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SOLAR HEAT—ITS INFLUENCE ON THE EARTH'S ROTARY VELOCITY.

BY CAPTAIN JOHN ERICSSON.

(*Continued from page 475.*)

(*See Frontispiece.*)

The last column of the table accompanying the previous article on this subject contains, it will be recollected, the amount of retardation caused by the waters of rivers flowing towards the equator. The computation of the retarding energy being based on the weight of water discharged and the increase of rotary velocity acquired during the transfer from the source to the outlet, no question can be raised as to the existence of the retardation entered in the table; but, whether compensating energies are called forth by the returning vapors before the condensation takes place, which results in the precipitation on the river basins, demands careful consideration. Dr. Mayer, in his discourse previously adverted to, positively asserts that, agreeable to the demonstration of Laplace, based on abstract mechanical principles, the compensating energy corresponds in every instance, with the amount of retardation to which the rotary motion of the globe may be subjected. Admitting this conclusion to be correct, we must assume the adequacy of the *vapors* which rise within the tropics to restore, during their transfer, to the temperate and polar regions, the loss of *vis viva* occasioned by the *water* flowing towards the equator. Obviously such restoration of energy can only be effected by friction or pressure of the vapors against projections on the earth's surface, directly or through the intervention of particles of the atmospheric air put in motion by the vapors. The Astronomer Royal of Sweden, in a recent communication to the Royal Academy of Sciences at Stockholm, in refutation of my assertion that solar influence is capable of diminishing perceptibly the rotary velocity of the earth, thus states the case: "The globe and its atmosphere constitute a combined system in motion, in which no part can by any outside cause be disturbed in its relative position without the motion of the entire system being thereby influenced. Consequently, a body of air which, for instance, is carried from the direction of the equator toward either of the poles, must, by degrees, positively part with the excess of rotary *vis viva* which it possessed at the commencement of the motion, compared with the rotary velocity of the region to which it has been transferred, and must impart the entire surplus to the earth undiminished, the rotation of which must consequently be accelerated by this current of air; and conversely a current of air of contrary direction, or from either of the poles towards the equator, must produce retardation. No difference can exist in this respect be-

tween a current of water and a current of air." The Swedish Astronomer, like Laplace, thus puts the whole question in a nutshell, asserting that air and water, water and air, may circulate in any manner whatever between the equator and the poles, and between the poles and the equator, without influencing the axial rotation of the globe. It is very true that the earth, with its rivers and atmosphere, constitute a "combined system in motion;" but we must not lose sight of the important fact that an *outside* energy, the sun's radiant heat, is being continually exerted, which interferes with the motions within that combined system. Accordingly, no argument can prove the correctness of the statement laid before the Royal Academy of Sciences at Stockholm short of a positive demonstration, showing that particles of vapor corresponding in weight with the water discharged by some river—say, the Mississippi—are capable of imparting by friction against the earth's surface, directly or through the agency of the atmosphere, a rotary force exactly balancing the retarding energy which we have established.

The advocates of the theory of compensation, while admitting that they cannot furnish any *practical* evidence of the truth of their doctrine, assert that the subject is not susceptible of experimental test. It would, indeed, be a fruitless task to undertake the construction of anemometers, or similar instruments, showing that the pressure and friction of the particles of the returning vapor exerted directly or through atmospheric intervention against the surface of the Mississippi river basin, from west to east, are capable of compensating the established retardation of 19,336,000,000 foot-pounds per second.

The admitted impossibility of proving by direct measurement the existence of compensating force, has suggested the resort to some indirect method. I have accordingly constructed an instrument which, practically, demonstrates the truth of the following proposition, on which the solution of the problem unquestionably depends. The retarding influence produced by currents of *water*, confined within channels which convey a given weight in a given time, from the pole to the equator of a rotating sphere, cannot be counteracted, or compensated, by opposite currents of *vapor* transferring an equal weight, in equal time over the surface of the said sphere from its equator to its pole.

The frontispiece represents the instrument adverted to; but before entering on a description, it will be well to define clearly the problem intended to be solved by experimental demonstration. The rotary velocity of the surface of the earth, for instance on the 45th parallel, is 1,074 ft. per second, that of the equator 1,519 ft. per second; hence the water of a river flowing from lat. 45 deg. to the equator, will have its velocity round the axis of the earth increased 1,519—1,074 =445 ft. per second. It needs no demonstration to show that the expenditure of energy necessary to produce this increase of rotary velocity will cause the earth to rotate at a diminished rate; the amount of retarding force being readily ascertained by multiplying the weight of water transferred, by the height necessary to generate a velocity of 445 ft. per second, viz., 3,094 ft. Consequently, each pound of water transferred from lat. 45 deg. to the equator, demands the expenditure of a dynamic energy of 3,094 foot-pounds. The question now presents itself, whether a pound of water evaporated on the equator, and returned in the form of vapor to lat. 45 deg., can during the return movement impart a rotary energy of 3,094 foot-pounds to the earth. Of course the vapor, on leaving the equator, possesses a rotary velocity of 1,519 ft. per second, while the surface of the earth in lat. 45 deg. rotates, as before stated, at a rate of only 1,074 ft. per second. It will be evident, therefore, that during the return movement the vapor, by contact with the earth, will have its rotary velocity diminished in the ratio of 1,519 : 1,074. On purely theoretical considerations, it must be admitted that this contact, by which the returning pound of *vapor* has its rotary velocity diminished 445 ft. per second, will restore to the earth the whole of the energy which was previously expended in augmenting the speed of the pound of *water* from 1,074 to 1,519 ft. per second during its transfer from lat. 45 deg. to the equator. But practice shows that rotary motion cannot be imparted to cylindrical or spherical bodies, however rough their surface may be, by currents

of air or steam, without great loss of mechanical energy. Conversely, currents of air or steam cannot be produced by the action of similar rotating bodies, without a corresponding loss of mechanical energy.

Practical engineers, familiar with these facts, fully appreciate the difficulty of instituting experiments intended to determine exactly what amount of force is expended in causing rotary motion by currents, and what amount of force is developed by currents produced by rotating bodies, as supposed. The illustrated dynamic register obviates this difficult comparison between energy expended and developed, by the simple expedient of applying heat and cold in such a manner that the *retarding* influence of a current of *water* flowing from the pole to the equator, acts simultaneously with the *accelerating* influence of an opposite current of *vapor*, transferring equal weight in equal time, from the equator towards the pole. The detail of the instrument will be understood by the following description. Fig. 1 shows a section of a hollow sphere 6.25 in. diameter, composed of brass of very light substance, made to revolve on its vertical axis; the upper half being covered with a light semi-spherical casing extending a short distance below the horizontal central plane of the sphere. A cylindrical cistern, provided with a flat cover, is attached to the top of the semi-spherical casing. The mode of supporting the lower pivot on which the sphere turns, as also the axle at the top, will be seen by reference to the drawing. Rotary motion is imparted to the sphere by a horizontal toothed rack (see top view, Fig. 2) working into the teeth of a wheel attached to the vertical axle; the motive power consisting of a weight suspended by a light cord passing over a pulley and secured to the rack. A circular gas pipe, provided with a series of burners, surrounds the sphere some distance below its centre. Referring to Fig. 2, it will be seen that the guide-pieces which support the horizontal rack and through which it slides, act as stops which regulate the the extent of the movement. It should be particularly noticed that the arrangement is such that when the motion is checked by the right-hand stop, the last cog of the rack has just slipped out of the cog-wheel, thus allowing the sphere to turn freely. The extent of motion of the rack is 0.186 ft., and the weight exactly 2 lbs.; it will be seen, therefore, that the motive force is 0.186 by 2 = 0.372 foot-pound or 2 by 7,000 by 0.186 = 2,604 foot-grains. Deducting the loss by friction, 64 foot-grains, the effective motive power will be 2,540 foot-grains. The axis of the sphere being exactly vertical, there is obviously no friction whatever at the upper bearing after the slipping of the last cog, of the rack, while the lower pivot presents a mere point of hardened steel to the step under it; hence the overcoming the atmospheric resistance against the outside of the sphere and the cistern, may be considered as the only work to be performed by the stated available motive power of 2,540 foot-grains. It only remains to be noticed that when the sphere is to be put in motion, the rack is geared into the cog-wheel and brought up against the left-hand stop, as represented in the drawing, the check lever, Fig. 3, being at the same time placed in the position shown by the dotted lines. The moment for starting, indicated by the chronometer, having arrived, the check lever is brought to the horizontal position as quickly as possible in order to prevent dragging at the moment of liberating the toothed rack. As shown by the illustration, a small quantity of water is confined within the surrounding casing of the sphere, thus forming an aqueous belt round its equator; the polar cistern being filled with water.

The object of the instrument having been clearly set forth, it scarcely needs explanation that the device is intended to show that when the heat of the gas flames is applied to the aqueous belt causing evaporation, while condensation is effected by the cold water in the polar cistern, the motive energy (2,540 foot-grains) will be incapable of turning the sphere as fast, and as long, as when heat and refrigeration are not applied. This assumption, it will be perceived, is in direct opposition to the views held by the Astronomer Royal at Stockholm and other followers of Laplace, who contend that "no difference can exist" as regards the effect on the axial rotation of the globe between currents of water and currents of aëriform matter transferring equal weight in equal time.

The mode of conducting the experiment with the dynamic register will be readily understood by the following explanation. The polar cistern is charged with boiling water and the gas flames applied for a few minutes until the water round the equator is brought near boiling heat. The gas is then shut off, and the toothed rack geared, and afterwards locked by the check lever. The chronometer being then carefully observed, the lever should be quickly pushed down when the hand marks exact time. The motive weight, being thus liberated, puts the sphere in motion through the intervention of the rack and cog-wheel, the time elapsing between the commencement of the movement and the slipping of the last tooth of the rack occupying about one second. The observation of the chronometer should continue in order to ascertain the exact time when the sphere is brought to rest. In the mean time the number of turns must be accurately counted. The first experiment being concluded, the sphere is again put in motion, as before, without changing the water in the polar cistern or applying the gas flames, the object of employing heat before starting being merely that of expanding the sphere to proper dimensions. The experiment having been repeated 6 times, the *mean* of time occupied, and number of turns performed, resulting from the expended energy of 2,540 foot-grains should be determined with the utmost precision. The procedure will then be changed; the polar cistern will be charged with *cold* water and the gas flames applied and kept burning. The sphere, under these altered conditions, is again started, but not until boiling temperature in the equatorial belt has been attained, and evaporation commenced. The experiment, as before, will be repeated 6 times, and the mean of time and the number of turns ascertained.

The law of compensation relating to solar influence on the axial rotation of the earth, expounded by Dr. Mayer, is evidently strictly applicable to the dynamic register since the equatorial belt of the rotating sphere is being continually heated while the polar region is being exposed to continuous refrigeration, vapor being thus formed at the equator, and currents produced which condense on reaching the cold semi-spherical covering over the pole. The water thus formed, divided into small streams, flows back on the surface of the sphere to the equator, where it is again converted into vapor; hence a continued circulation of opposite currents of vapor and water will be kept up. It should be particularly observed that the vapor in its passage towards the pole, not only acts against the surface of the sphere, but also against the inside of the semi-spherical covering, thereby affording a double chance of imparting motion to the rotating mass. But, this notwithstanding the experiments have shown that the *retarding* energy of the condensed water flowing in small streams from the pole to the equator on the surface of the sphere, greatly exceeds the *accelerating* energy imparted by the excess of rotary velocity of the vapor in its course towards the pole, and the consequent friction of its particles against the surfaces of the sphere and the semi-spherical casing. Agreeable to Dr. Mayer's conclusions, founded on the theory of Laplace, the opposite currents which result from high temperature on the equator, and the refrigeration over the temperate zone and the poles, cannot affect the axial rotation of the globe. "The effect of every single motion by these means on the rotation of the globe," he says, "is exactly compensated by the effect of another motion in an opposite direction." Nor can the Swedish Astronomer, as we have seen, perceive any difference between currents of water and currents of aëriform matter. In direct opposition to the conclusions of these savans, our experiments prove that, although the weight transferred from the pole to the equator of the sphere of the dynamic register is precisely the same as the weight which is transferred in the opposite direction, the contact and friction of the particles of vapor against the surfaces of the convex and concave spheres, is incapable of restoring the loss of *vis viva* consequent on imparting rotary motion to the particles of water transferred from the pole to the equator.

Our space not admitting of a detailed account of the experiments which have been made with the dynamic register, a few important facts only will be noticed in this article. The number of turns of the rotating sphere produced by the

motive force of 2,540 foot-grains, has been 660.5 occupying 10 min. 37 sec., the barometer at the time indicating 29.8, the temperature of the surrounding atmosphere being 62 deg. The mean of the force expended for each turn will therefore amount to $\frac{2540}{660.5} = 3.84$ foot-grains. It will be asked in view of this insignificant motive power, chiefly expended in overcoming the atmospheric resistance against the rotating sphere and cistern, how the excess of retarding energy of the condensed water flowing from the pole to the equator, can possibly be measured. The answer is, that we need not consider the amount of energy developed by the motive weight; we merely count the number of turns, and note the time required to bring the sphere to a state of rest from the moment of starting, the gas flames being kept burning and the refrigerating medium retained in the polar cistern during the observations. Then removing the cooling medium and replacing the same with boiling water, we again put the sphere in motion, count the number of turns and note the time. The result of this change of procedure will be, as shown by our experiments, that the sphere will run much longer and perform a greater number of turns—a startling fact, since the motive energy of 2,540 foot-grains has not been increased. To practical minds the explanation will at once suggest itself, that because there is an *expenditure of heat* while condensation is kept up, which ceases when the refrigerating medium is withdrawn, some additional work is being performed while the cold medium remains at the pole. Now, what is the nature of this work? Evidently the condensed water while flowing from the pole to the equator has its rotary speed successively increased corresponding with that of the surface of the sphere; hence work must be performed while refrigeration is kept up at the pole. Satisfactory as this explanation appears, it is met by the cardinal objection, that since force cannot be annihilated, the opposite current of *vapor* which simultaneously transfers an equal weight from the equator to the pole of the rotating sphere, must, by friction or contact of some kind, positively return the whole of the mechanical energy expended in augmenting the rotary velocity of the particles of water moving in a contrary direction. This, notwithstanding, we must accept the *fact* proved by the dynamic register, that a certain amount of mechanical energy *disappears* when the rotating sphere is subjected to the action of differential temperatures. There was a time when we could not account for such disappearance of energy, but—thanks to the labors of Joule and Mayer—the mechanical theory of heat has thrown light on the subject. The theoretical deductions of Laplace have lost their potency. We no longer confine ourselves to the balance and rule in measuring the result of expended force. Joule and Mayer have taught us to consult also the *thermometer* during our investigations. Bearing in mind, then, what the new theory of heat teaches, the disappearance of mechanical energy during the experiments with the dynamic register, ceases to be a puzzle. Close investigation shows that the heat resulting from the arrested motion of the circulating vapor, which, on leaving the aqueous belt, possesses a rotary velocity equal with that of the circumference of the sphere, represents very nearly an equivalent of the observed loss of energy; the difference being made up by heat generated by the particles of the circulating vapor as they successively impinge against the minute projections of the surface of the convex and concave spheres. Obviously the heat thus generated is carried off by the cold semi-spherical casing surrounding the sphere of the dynamic register, precisely as heat produced by analogous motions within the terrestrial atmosphere is carried off by radiation into space. In either case, the heat lost is an exact equivalent of the mechanical energy abstracted from the rotating sphere.

George H. Stem & Co., of Stemton, Northampton county, Pa., employ 160 men in their car works, have three full sets of machinery, and are able to turn out twelve 6-ton coal cars per day by working overtime.

It is stated that in European Russia there are 19,266,667 horses, or 260 for every 1,000 men.

THE WORKING EXPENSES OF STEAMERS OF SMALL SIZE.

By A. F. YARROW, Esq.

From the "Journal of the Society of Arts."

Steam launches have for several years been extensively adopted in Norway and Sweden, carrying on there successfully the traffic across the many estuaries and fiords formed by a very irregular coast line. It is, however, only within a comparatively recent period that these little craft have become generally known in this country. To identify more particularly the type of boat I am now referring to, I may mention that they vary from 30 ft. to 60 ft. in length, and from 6 ft. to 12 ft. in beam, generally have no neck, and are propelled mostly by one, but occasionally by two screws, driven by high-pressure direct-acting engines.

One of the first successful attempts made in this country to develop passenger traffic by boats of this type was started at Plymouth, in 1869.

A small company was formed, called the Oreston Steamboat Company, with a view to run between Plymouth and Oreston, calling at Hooe, Turnchapel, and Mount Batten, the only communication at the time being by watermen's boats, or a three-mile walk and a toll of one penny.

The first steamer purchased was called the Little Pet. It was 40 ft. in length by 7 ft. 6 in. beam. The success of this boat induced the company to order another (which was called the Favorite), 50 ft. in length by 10 ft. beam, driven by a pair of 5½ inch. cylinders, and licensed by the Board of Trade to carry 84 persons. The average time occupied by this boat in the run of 1¾ miles, was fifteen minutes, including stoppages, and the fare charged 1d.

There was no deck whatever, but a cabin, the full width of the boat, and 10 ft. in length, was provided aft. The draught of water, when at work, was 3 ft., with a speed, over a straight course, of 8 to 9 miles an hour.

To show more clearly the exact nature of the traffic carried on, I beg your reference to the rough map of Plymouth. At the Barbican-pier the boats run alongside the quay, and at Oreston there is a small jetty; but at Hooe, Turnchapel, and Mount Batten the boats are generally run on to the beach, and a plank thrown out forward for the outgoing and incoming passengers. This simple means appears to answer the requirements of the case, and the boats, which are strongly built of wood, and suitably shaped to take the ground, do not materially suffer.

A considerable business is done in taking off and putting on board passengers from the vessels lying at the anchorage in the Catwater; and, if hailed from the shore, the boats are frequently beached to take people up.

Gained from the experience of this company, the cost of working such a launch as the Favorite, running 24 journeys per day of 12 hours, each journey being 1¾ miles, it has been found that the consumption of fuel has been 8 cwt. per day, and the consumption of fresh water 350 gallons per day. I may here mention that water tanks are fitted to this boat sufficient for 4 hours' constant steaming, these tanks being replenished from time to time by the hose at the quay.

The crew consists of a captain, receiving 24s. per week, engine-driver, 21s. per per week, and a collector, 18s. per week.

These and other expenses I have tabulated, the total working expenses per week being £8 12s. 11d.

This company has attained considerable success; the credit for which is mainly due to Mr. Edmund Jones, a resident of Plymouth, who writes as follows:

"During the past summer, each of the three boats has earned occasionally as much as £20 per week, and the opposition company, who have also three boats, nearly as much. The cost of repairs, however, is very heavy; the watermen, who show a most determined hatred to the boats, do much injury; and for a long time we had always to keep a watchman on board to guard against malicious damage; and what with racing with the opposition, and consequent coal-wasting, lawsuits, summonses from the watermen whenever we by chance carried over our legal number, we have had a tough lot of battling, gaining, by paying dearly, valuable experience. During the last dry summer the fresh water supply ran short, which caused much injury to the boilers

from want of sufficient care in constantly blowing off, to prevent incrustation when feeding from the sea. The boats, however, after paying for all this, as well as putting by towards renewal fund, have given a very good profit."

We will now just glance at quite a different style of steamer, one which I have specially selected as doubtless familiar to us all—I refer to those running on the Thames between London and Westminster bridges and intermediate piers.

They average 110 ft. in length by 14 ft. beam, being certified to carry 370 passengers, and are propelled by condensing paddle engines of 24 horse-power nominal.

To give some idea of the cost of working such a steamer, I have tabulated the expenses at £29 4s. 9d. per week.

These boats are of a type doubtless well designed and ably managed, but I contend that they are unsuited for the work to be performed. Boats of smaller size, such for example as the one I have briefly described, would, in my opinion, fulfil the requirements of the case much better. They could be more numerous, leaving the piers more frequently; they would be much more easily handled and brought up alongside the landing stages; a very much smaller original outlay would be requisite, as well as greatly reduced working expenses. I will admit that during certain hours of the day in fine weather in the summer months, the present steamers will have their full complement of passengers; but it is clearly an error to entail excessive working expenses during the whole year, for the sake of rendering available the maximum traffic during a very limited period.

When running in fresh water, on lakes or rivers, the extreme simplicity of the ordinary type of steam launch enables it to be worked with perfect safety and success, by any one of moderate intelligence and care; but when used at sea, where salt water only can be obtained for the supply of the boiler, the difficulties are greatly augmented, owing to the risk entailed from incrustation and eventual destruction of the boiler. Whatever care may be requisite on board ocean steamers worked by competent men, even still greater care is required with high-pressure engines, the boilers adopted as a rule having much greater evaporative power in proportion to their contents.

With the aid of the salinometer, the amount of brine requisite to be blown off to prevent salting up can be carefully regulated, and the boiler preserved for many years in perfectly good condition. This, however, requires an amount of care and attention which experience has proved to be most difficult to obtain even in this country; and abroad, in places where skilled labor is scarce, it is sometimes simply impossible. In all cases where a supply of fresh water can be procured on shore, it is unquestionably desirable to have tanks fitted on board from which to feed the boiler, and if these tanks hold sufficient to last until they can be replenished, the boat can be worked without any special care. The use of the ordinary surface condenser is one mode of obtaining a supply of fresh water; but the great complication of such means is a serious barrier to its adoption, sacrificing at once the marked feature of the steam launch, which is its simplicity, in addition to increasing the cost, and depriving the boiler of the benefit of the blast up the chimney.

It has frequently been proposed, and even tried, to condense the steam by passing the exhaust pipe along the outside of the boat, the external surface coming in contact with the water, and thereby condensing the steam within. I am not aware of any trials of this kind which have proved successful until the middle of last year, when Mr. Alexander Crichton, of Cork, fitted two Government steam launches with such apparatus. These launches were of the well-known twin-screw type, having two cylinders to each screw secured to the sides of locomotive boilers. The exhaust pipes were passed through the boat's bottom, and carried alongside the keel for 14 ft., and then returning 16 ft. re-entered the boat, and were at once connected to two small air-pumps worked by eccentrics. These air-pumps delivered into a hot well, to which the suction of the feed pumps was attached. Under these circumstances the whole of the exhaust steam was condensed and returned to the boiler as fresh water, the only loss worthy of notice being that due to the steam-jet, which had to be kept going in the funnel to

maintain the requisite draft. In both these launches there appeared to be a considerable gain both in power indicated as well as in speed. The capacity of the air-pumps, which were single acting, was 1-20th the capacity of the cylinders. There can be no possible doubt that if these results can be confirmed over a lengthened period, that they are indeed most valuable, and great credit is due to Mr. Crichton.

We ourselves last month tried some experiments in the same direction, with a small wooden tug boat we have just completed for the Brazils, in which it was a most essential point to carry water and fuel for as many hours as possible.

The boat was 37 ft. in length, 9 ft. in beam, and 5 ft. in depth. The engine consisted of a single cylinder, 9½-in. diameter by 12-in. stroke, and the boiler of the usual return tube type. As the boat was small for the weight of machinery, there was not buoyancy left sufficient to carry the desired quantity of fresh water. We therefore considered this a specially favorable instance for testing the merits of this system. All we were anxious to do was to secure the return of the bulk of the water to the boiler, at the same time retaining amply sufficient blast.

The exhaust pipe was passed to the forward end of the boat, terminating in a breeches-piece, which went through the skin on each side of the keel. To this were secured two 3-in. copper pipes, each 21 ft. long, running along the boat's bottom towards the stern. At the after end of these pipes was attached another breeches-piece, which re-entered the boat, and was connected to the suction of a small plunger pump 1¾-in. diameter by 6-in. stroke, worked by an eccentric from the screw shaft, as shown. This pump delivered into tanks placed on each side the boat. The inclination of the condensing tubes, when the boat was running, was about ⅝ of an inch to the foot.

We provided means for conducting the exhaust either wholly up the chimney or partially into the chimney and partially into the condensing tubes, always retaining ample collective area for the steam to pass through, which was never less than equal to an orifice of 2¼ in. diameter.

Over a lengthened trial the following were the results obtained, which I have tabulated on sheet 6: Consumption of midland coal per hour, 120 lbs.; evaporation of water, 780 lbs.; pressure of steam per sq. in., 54 lbs.; estimated indicated horse-power, 20½; revolutions per minute, 120.

Under these circumstances, we found three-fourths of the steam could be condensed without apparently injuring the draft, the remaining one-fourth passing up the funnel: The exact quantity of water delivered back into the tanks was, per hour, 580 lbs.; the temperature of the water in the river being 44 deg.; the temperature of water pumped from condensing tubes, 59 deg.

The following will be the practical bearings of these results, which are tabulated on sheet 7: Presuming the tanks and boiler to be filled with fresh water, and worked in the ordinary way, the tanks, which contain 320 gallons, will be emptied after 4 hours' steaming. If the condensing apparatus be at work they will be emptied after 16 hours' steaming.

We will now assume that, after the expiration of these times, we are forced from necessity to pump from the sea, and we will also assume that the water in the boiler must never have in solution more than $\frac{3}{33}$ its weight of salt, and that up to that time there is no fear of incrustation.

The boiler contains about one ton of water, and as the sea holds in solution $\frac{3}{33}$ its weight of salt, it is clear that 3 tons of water must be evaporated and replaced by 3 tons of sea-water before $\frac{3}{33}$ of salt will be present in the boiler. This would occupy in the ordinary way 8½ hours additional. If with condensing apparatus at work, 34 hours additional. We therefore finally arrive at the fact, that the total length of time the boiler can be worked with perfect safety from first starting, without risk of incrustation, will be: With fresh water tanks only, 12½ hours; if with condensing apparatus, 50 hours.

For the sake of comparison I have added the time that it would require, if salt water only were used for the boiler, for it to arrive at the same degree of saturation; this could be attained after the evaporation of 2 tons of water, which would occupy 5¾ hours.

I will make no remark on these figures; the practical results are clear without further comment.

The boat upon which these experi-

ments were tried was of wood, but had it been of iron the condensation of the exhaust steam would have been even more readily effected, the condensing pipes would have been quite unnecessary, the skin of the boat itself serving equally well as the conducting medium. To illustrate one practical method of carrying this out, I beg your reference to sheet 8. That portion of the exhaust to be condensed would be passed into a receiver, of which the skin of the boat would form its external side; assuming the frames of the boats to be 18 in. apart, ample area would be obtained if the space between three frames be taken, and from the water level on the one side to the water level on the other, this would not only form a suitable reservoir for receiving and condensing the steam, but would give additional stiffness to the hull at the very place required, as well as serve as a substantial platform for the engine. The feed-pump could take its suction, as shown, and force direct into the boiler, no additional pump being required.

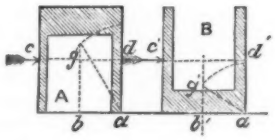
As to whether this plan is capable of extensive adoption (which I firmly believe), it is not for me now to enter; but it is certain the required end is obtained at a nominal cost, and without additional complication.

THE STABILITY OF ROLLING STOCK.

From "Engineering."

In the course of recent articles on narrow-gauge railways and their rolling stock we have, on several occasions, spoken in general terms of the lateral stability of such stock, and promised that we should take an early opportunity of considering the subject in greater detail. This promise we now propose to fulfil, and we cannot perhaps do better than commence by explaining exactly what we mean by "lateral stability." The "lateral stability" of a railway vehicle is of two kinds; first, its statical stability or its resistance when in a state of rest, to be upset by a steadily applied lateral force; and second, its stability—or to use a more expressive term, perhaps, its steadiness—when in motion, or its power to resist the setting up of lateral oscillations by the inequalities of the road. The statical stability of any vehicle of a given weight and placed on a line of given gauge, of which the rails are at the same level, is unaffected by the width of that vehicle or the height of its centre of gravity above the rails, while it is influenced, in most cases which occur in practice, in but a moderate degree by the flexibility of the springs and their position. On the other hand, the stability while in motion—or, as we shall term it for the sake of distinction, the "steadiness"—of a vehicle is considerably affected by the height of the centre of gravity above the rails, by the width of the vehicle and the lateral distribution of the weights, and by the flexibility of the springs and their arrangement, while it is influenced to a very important extent by the state of the line, and the speed at which the latter is traversed by the vehicle. We shall in the present article consider the statical stability of rolling stock only, leaving the question of the "steadiness" when in motion, to be considered on a future occasion, and we shall confine our attention solely to the resistances

FIG. 1



to forces acting laterally, as being those principally affected by the width of the gauge on which a vehicle runs.

In the case of a vehicle not mounted on springs, and of which the weight is known, the determination of the statical stability is an exceedingly simple matter. In such a case the stability is, as we have stated, independent of the height of the centre of gravity above the rail level, and depends simply upon the weight of the vehicle and width of gauge of the line on which it is situated. That this is the case will readily be understood on a reference to Fig. 1. In this figure a body of ⊔ section is represented in two positions, A

and B, the body being in each case supposed to be acted upon by a force applied in the direction of the arrow, and tending to produce the overturning of the body on the corners, a and a', respectively. In the case of the position A, the centre of gravity is situated at the height, $g\ b$, above the base line, while in the case of B, its height above that line is but $g'\ b'$, or about half as much as in the former instance, but it is evident that this in no way affects the resistance to the overturning force. In each case that force acts, as it were, at the end of the arm of a lever of the length, $a\ d = a'\ d'$, and in each case the righting moment opposed in this force is equal to the weight of the body acting at the end of the arm of a lever of the length, $a\ b = a'\ b'$. The moments of the overturning force and the righting moments are thus the same in the two cases, and the height of the centre of gravity above the base has therefore no influence upon the statical stability of the body.

We have explained this matter at a greater length than it, from its elementary character, perhaps deserves, because we have noted that some railway engineers appear to imagine that the resistance of a railway vehicle to being overturned by the wind is influenced by the height of the centre of gravity above the rail level, whereas this height has practically, as we have shown, nothing whatever to do with the matter, so long as the vehicle is standing on a portion of the line having the rails on the same level. The manner in which inequalities in the levels of the rails affect the stability we shall show presently. It is true that the lower the centre of gravity the greater is the angle through which the vehicle has to be canted before there ceases to be any righting moment; but this fact is of no practical value as far as the statical stability is concerned, as with all positions of the centre of gravity occurring in practice the righting moment decreases as the vehicle is canted over in a much more rapid ratio than the effective pressure of the wind is diminished by the inclination of the surface on which it acts, and thus the power to resist any given wind pressure decreases as the canting proceeds.

In case of a railway vehicle with wheels in good condition, standing on a well laid line, the points of contact of the wheels and rails are generally situated at about the middle of the width of the latter, and the breadth of base to be taken in calculations, referring to the lateral stability, may therefore in such instances be assumed to be equal to the distance between the rail centres. Inasmuch, however, as from the wear of the tyres, or the canting of the rails in bad portions of a road, the points of contact between the wheels and rails may be shifted to near the inner edges of the latter, it is safer in calculations of the kind to which we are referring, to assume the breadth of base to be equal to the width of the gauge; and it is this breadth of base which we have taken in all our calculations.

The actual width of base may in fact vary in practice to the extent of about twice the width of the heads of the rails, and, in the case of lines of very narrow gauge, this variation will occasion an important percentage of variation in the resistance of vehicles to forces tending to cant them laterally; while the wider the gauge the less will be the proportionate alteration in the stability due to the shifting of the points of contact between the wheels and rails from the outer to the inner edges of the latter, or *vice versa*. It will thus be seen that in the case of very narrow gauge lines, it is important that the width of base should be taken as equal to the gauge only, if it is desired to obtain results which are reliable under all circumstances.

In the case of the force tending to produce overturning being that due to the pressure of the wind, this pressure may be considered to be all concentrated at the point representing the centre of gravity of the exposed side area, and for convenience we shall term this point the centre of pressure. To obtain the total pressure of wind required to just balance the righting moment of the vehicle, we have thus only to multiply the weight of the vehicle in pounds by the half width of the gauge, and to divide the product by the height of the centre of pressure above rail level. Of course the half-width of the gauge and the height of the centre of pressure above the rail must be expressed in the same unit of measurement. Dividing the total pressure obtained, as above, by the side area in sq. ft., we get the required pres-

sure of wind per sq. ft. Expressed algebraically the rules become :

$$(1.) \quad . \quad . \quad . \quad P = \frac{W\,b}{H}.$$

$$(2.) \quad . \quad . \quad . \quad p = \frac{P}{a} \text{ or } = \frac{W\,b}{H\,a}$$

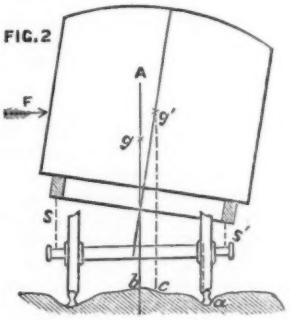
in which formulæ, P = the total lateral pressure; p = the pressure per sq. ft. on the side area; H = the height of the centre of pressure above the rails; b = the half breadth of the gauge expressed in the same unit of measurement as h ; and a = the exposed side area in sq. ft. It has been sometimes urged as an excuse for proposing the use of vehicles possessing an insufficient resistance to the lateral pressure of the wind, that the direction of the latter is but rarely directly at right angles with the side of the carriage and that, therefore, the effective pressure is reduced. It is quite true that the effective pressure exerted by a wind of any given force varies directly as the sine of the angle enclosed between its line of direction and the plane of the surface on which it impinges; but those who urge the argument above referred to appear to forget that the sine of the angle just mentioned decreases but very slowly for the the first 20 deg. or so from a right angle. Thus on referring to a table of natural sines it will be seen that the effective pressure exerted by any given wind upon the side of a vehicle will vary as follows, according to the angle which its direction forms with the surface on which it strikes :

Angle enclosed between line of direction of wind and the side of the vehicle. deg.	Effective pressure of wind given in percentages of the pressure which would have been exerted by it if its line of direction had been at right angles to the side of the vehicle, per cent.
80	98.48
70	93 97
60	86 6
50	76.6
40	64.28
30	50.00

It will be seen from the above table that the deviation of the direction of the wind to the extent of 10 deg. from the perpendicular decreases the effective pressure but about 1½ per cent., while it is not until that deviation becomes as great as 60 deg. that the effective pressure exerted is reduced one-half.

We have now to consider the extent to which the general deductions above arrived at are modified by the fact of a vehicle being mounted on springs. In the first place, the springs may be considered to divide the vehicle into two parts, the upper one of which, or that situated above a plane passing through the points of bearing of the springs, may be canted to a certain extent without affecting the part situated below that plane. Fig. 2, which represents in an exaggerated degree the action to which we refer, will explain our meaning clearly.

FIG. 2



An examination of this figure will show that when a vehicle mounted on springs is subjected to a lateral pressure exerted against the side of the body, either the body may be canted on the springs or the whole vehicle may be canted together on one of the rails as a turning point; and which of these actions will take place depends upon the following considerations: The moment of the force tending to produce a canting of the upper part of the vehicle upon the springs is equal to the pressure exerted against the side surface multiplied by the height of the centre of pressure above the plane passing through the bearing points of the springs ; whilst the moment of resistance to this force would, if it were not for the elasticity of the springs, be equal to the weight of that part of the vehicle resting on the springs multiplied by the half distance between the spring centres. Thus if s = the half distance between the springs ; w = the weight of that portion of the vehicle carried on the springs; and h = the height of the centre of pressure above the plane passing through the bearing points of the springs; then the force F, required to produce a canting of the upper part of the vehicle on the springs would, if it were

not for the elasticity of the latter, be given by the following simple formula:

(3.) . . . $F = \frac{w\,s}{h}$.

On the other hand, the pressure, P, required to cause the whole vehicle to be canted on one of the rails, is given by formula (1) and under the circumstances we have supposed, it would evidently depend upon whether P was greater or less than F, whether the upper part of the vehicle would be canted on the springs, or the whole vehicle on the rails, under the action of a lateral force. In the case of vehicles mounted on very rigid springs spread at a good distance apart, the formula just given may be used without incurring any error of practical importance; but if the springs be very flexible—deflecting, say 2 in. or 3 in. per ton of load, or if their distance apart be small, it may be necessary to take into consideration the manner in which the elasticity of the springs affects the stability of the vehicles. Theoretically it is correct that the influence of this elasticity should be taken into consideration in all cases, but practically—with the proportions of rolling stock ordinarily met with—the influence of this elasticity on the statical stability of a vehicle is so small that it may in the majority of instances, in the case of rolling stock for broad gauge lines, be neglected altogether. In the case of narrow gauge stock the influence of the elasticity of the springs is more important as the following example will show.

Let us, for instance, suppose the case of a four-wheeled carriage on a line of 3 ft. gauge, this carriage having a side surface of 150 sq. ft. and being exposed to a wind pressure equal to 10 lbs. per sq. ft. Let this carriage be mounted on springs deflecting 1 in. for each 750 lbs. of load, and placed at a distance of 4 ft. 8 in. apart from centre to centre (the half-width, s, being thus 28 in.), and let the height of the centre of pressure above the plane passing through the bearing points of the springs be 3 ft. 6 in. Finally, let the centre of gravity of that part of the vehicle mounted on the springs be situated 2 ft. 8 in. above the plane just mentioned.

The pressure of the wind will cause an increase in the load on the springs on the lee side of the carriage and a corresponding decrease of load on those on the opposite side; the *difference of load* on the two sides, amounting under the circumstances above supposed to $\frac{150\times10\times42}{28} = 2{,}250$ lbs. In other words, the load on the 2 springs on the lee side will be increased 1,125 lbs. or 562½ lbs. per spring, and the load on those on the opposite side decreased to an equal amount. The elasticity of the springs being such that they each deflect 1 in. under a load of 750 lbs., the inequality of load above mentioned will result in an additional deflection of ¾ in. in the springs on the lee side and a rise or decrease of deflection of an equal amount in the springs on the other side, the upper part of the carriage being thus canted to an extent measured by a difference of 1½ in. in the level of the bearing points of the springs on the opposite sides. Multiplying now this 1½ in. by 2 ft. 8 in. and dividing this product by 2 ft. 4 in., we get $\frac{1.5\times32}{28} = 1.714$ in. as the amount to which the centre of gravity of that part of the vehicle carried by the springs has been shifted laterally by the unequal deflection of the springs on the two sides.* Referring now to Fig. 2, we may suppose g' in that fig. to represent the altered position of the centre of gravity of that part of the vehicle carried by the springs, and it will be seen that the resistance offered by the weight of that portion to the overturning of the vehicle on the point a, is diminished by the canting on the springs in the proportion of $a\,c$ to $a\,b$. But we have shown that $b\,c = 1.714$ in. and as $a\,b$ = half the width of the gauge = 18 in., that part of the resistance to overturning due to the weight of the spring-carried portion of the vehicle has been diminished in the proportion of 16.286 to 18, or about 10½ per cent.

If now the weight of that portion of the vehicle carried by the springs amounts to ¾ths of the total weight, we shall have the stability of the vehicle, considered as a whole, diminished to the extent of

$$\frac{10.5\times3}{4} = 7.875$$

per cent. by the canting of the upper part of the springs.

We have supposed, in the above example,

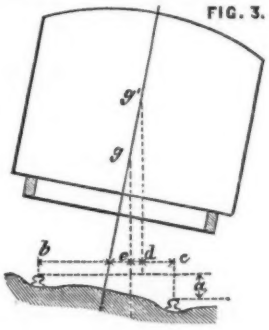
* In reality, this shifting of the centre of gravity laterally would of itself throw an extra load on the springs on the lee side, and thus cause their additional deflection. To avoid complication, however, we have neglected this small increment of deflection.

that by the time the upper part of the vehicle was canted to the extent stated, the difference in the pressures on the springs, s and s' (see Fig. 2), was sufficient to cause the canting, on the point a, of those parts of the carriage below the spring. It is probable, however, that, with the proportions of parts ordinarily met with in practice, this difference of pressure would *not* be sufficient to produce the result supposed, and, under these circumstances, an increased lateral pressure would be required to produce the overturning of the vehicle, and this increased lateral pressure would be attended with an increased canting of the upper part of the vehicle on its springs, and consequently a further reduction of its stability.

A consideration of the facts above stated leads to three important practical deductions. The first of these is, that the higher the centre of gravity of the spring-carried portion of the vehicle is above the plane passing through the bearing points of the springs, the greater is the reduction of the stability due to canting of the upper portion of the vehicle in the manner represented in Fig. 2; while the second deduction is that it is extremely important to give to narrow-gauge rolling stock as wide a spring base as possible, and to regulate the flexibility of the springs according to the width of spring base attainable. The third deduction is that in the case of vehicles carried on bearings situated inside the wheels, the resistance to the overturning of the upper part of the vehicle on the springs is always less than that opposed to the overturning of the whole vehicle on the rails; and consequently that in order that the latter event may take place, it is necessary that the springs should be actually coupled to the upper part of the vehicle, and not merely bear against it. Otherwise, the weights of those portions of the vehicle not carried on the springs possess no influence on the stability of the whole.

We now come to the last point which we intend to consider in the present article, and that is the influence of an inequality in the level of the rails, on the stability of a vehicle. Fig. 3 will illustrate the effect of such an inequality. In this figure one rail is represented lower than the other to the extent a; and if we suppose that the centre of gravity of a vehicle standing on this line be situated at g, it will be seen that the righting moment,

FIG. 3.

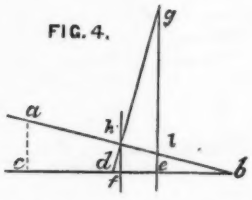


tending to prevent the overturning of the vehicle towards the lower side, will only be equal to the weight multiplied by the distance, $c\ e$; or, in other words, it will be less than the righting moment which exists when the vehicle is standing on a level line, by as much as $c\ e$ is less than half the width of the gauge, $c\ d$. It will also be noticed that whereas when a vehicle is standing on a level line, the height of the centre of gravity exercises no influence on the statical stability of the vehicle, on a line having one rail lower than the other, the position of the centre of gravity is of considerable importance. Thus, in the case shown in Fig. 3, if the centre of gravity of the vehicle was situated at g' instead of g, the righting moment would be reduced in the proportion of $d\ c$ to $e\ c$, the lines $g\ e$ and $g'\ d$ being, we need hardly say, perpendiculars, let fall from the respective centres of gravity, g' and g'.

Very little consideration is required to show that, other things being equal, the effect of any given inequality in the level of the rails upon the stability of a vehicle placed on them will vary directly as the gauge of the line. It will also be seen that the *actual amount* of the reduction in the stability due to any given inequality of level of the rails will be directly proportionate to the height of the centre of gravity of the vehicle above the latter, the *percentage* of the reduction, however, being dependent, not on the height of the centre of gravity alone, but on the proportion between that height and the width of the gauge. For instance, in Fig. 4, let $a\ b$ be a line joining the heads of two

rails, of which one is higher than the other by the amount $a\,c$, and let g represent the position of the centre of gravity of a vehicle standing on such a line. Then $g\,h$ drawn perpendicular to $a\,b$ represents the height of the centre of gravity above the rail level when the vehicle is standing on a line of which the rails are at an uni-

FIG. 4.



form height, and $g\,e$ is a perpendicular drawn from the point g to the level base line, $c\,b$. In this figure it is evident, from what we have already stated, that if the half breadth of gauge, $h\,b$, be taken as representing the stability of the vehicle when standing on a line having the rails at the same level, then $h\,i$ will represent the amount of reduction of that stability due to the canting of the line to the extent, $a\,c$, and the fraction $\frac{h\,i}{h\,b}$ will represent the *proportionate* reduction of stability thus effected. Moreover, it is evident that $a\,b\,c$ and $g\,h\,i$ are similar triangles, and thus

$$h\,i = \frac{c \times g\,h}{c\,b}. \quad \text{But } c\,b = \sqrt{a\,b^2 - a\,c^2},$$

and substituting this value in the preceding formula, the value of $h\,i$ can readily be calculated whenever the width of gauge, difference of level of the two rails, and height of the centre of gravity of the vehicle above the rail level, are known. For instance, let G = the height of the centre of gravity above the rail level; b =, as before, the half-width of gauge; x = the amount to which one rail is above the level of the other; S = the moment of stability of the vehicle when standing on a line with rails at the same level; R = the moment of stability of the same vehicle when standing on a line having one rail higher than the other by the amount x; and W =, as before, the weight of the vehicle. Then

$$(4.) \quad . \quad . \quad S = W\,b; \text{ and}$$

$$(5.) \quad . \quad . R = S \frac{b - \frac{x\,G}{\sqrt{i^2\,b - x^2}}}{b}.$$

This formula merely gives the reduced stability due to the unequal level of the rails, and does not take into account any further reduction due to the action of the springs. This further reduction may, however, be readily ascertained in the manner we have already explained. The present article has already reached such a length that we must forbear from saying anything more concerning the stability of rolling stock here; but we intend to return to the subject, and point out the manner in which the width of the gauge and the proportions of the vehicle affect the steadiness of the latter when running over a line having such inequalities as are ordinarily met with in practice.

STEAM FIRE ENGINES FOR JAPAN.—Messrs. Merryweather and Sons have just completed two of their 300 gallon steam fire engines for the Government of Japan. Each engine is fitted with a large quantity of delivery hose and every requisite. On testing them before shipment each raised steam from cold water in 8 min. A steam fire engine of a similar construction, but more powerful, has been forwarded this week to the Marquis of Exeter, Burghley House, Stamford. The engine was teste l in the presence of the Marquis and many of the surrounding gentry and nobility, and gave great satisfaction. This engine discharges 450 gals. per min., and raises steam in 8 min. Had such an engine been at Holker, the Duke of Devonshire's seat at Cartmel, we should not have had to record a total loss of one wing of the noble mansion, estimated at £30,000.

THE new furnace of the Leland Lake Superior Iron Co., situated on the Eastern shore of Lake Michigan, opposite Green Bay, was successfully blown in on the 22d ult. The height of the stack is 52 ft.; diameter of bosh, 10 ft. 6 in.; casting house, 70 x 50 ft. The blowing cylinder and machinery are driven by two 65 in. Houston turbine wheels. Ten charcoal kilns, 56 x 18 and 20 ft. high, have been built on the bank of Carp River, which, with the lakes tributary to it, will furnish an inexhaustible supply of hard wood for charcoal. The furnace and kilns have cost about $86,000 and 25 tons of iron can be turned out daily.

SUBURBAN RAILROADS—THEIR CONSTRUCTION AND OPERATION.

By T. McDONOUGH.

At the time when the various lines of railroad leading from New York into the interior were built, the principal object was to accommodate a mixed traffic of freight and passengers, carried over long distances; and the consolidation of lines stretching far westward, with the profit resulting from it, has made the short traffic of comparatively less importance as a source of income, under the present method of managing it. As the short traffic has gradually increased so as to require special trains, these have been merely duplicates of those used for long travel.

In reviewing the methods proposed, as adapted to the requirements of this short traffic, prominence has lately been given to roads of narrow gauge, on account of their financial success in Wales, and also in some parts of the Continent of Europe. It is claimed that these roads are cheaper to build as well as more economical to operate.

The principal saving in cost of building such roads is made up as follows: In the quantities of land required, and of excavation and embankment; in the use of shorter ties; and also the saving in cost of equipment; as such roads require light engines and cars. The saving in construction may be about as follows: When a road has light cuts and fills of not more than 15,000 cubic yards to the mile, there will be about ⅓ less earth to be moved. But this saving will be rapidly lessened when the cuttings are deeper than 6 ft., the saving being only made in the road bed, which is only a small part of the excavation in deeper cuttings. In these the slopes furnish most of the material. These require the same amount of earth to be removed for a narrow bed as for a wide one, so that with any work, except that under 6 ft. depth of cutting or height of embankment, the saving will be inconsiderable. The ties will be shorter by the difference between a 3 ft. and a 4 ft. 8½ in. gauge, which is the difference between the width of the two systems, the present one and that under consideration.

The above are the principal items in which any saving can be made, for cheap and light cars can be used on either gauge; but those on the present gauge will give more accommodation to passengers. With these slight advantages, there is the serious drawback, that such roads, if they enter upon those now built, will require a third rail to be laid for their use. This objection will have force upon any lines to be laid near the large cities, though there may be exceptional cases where it does not apply. There being no advantages in the 3 ft. gauge sufficient to recommend it in preference to that used at present, the various modes proposed for the accommodation of the short traffic on the present lines will now be considered. That one now adopted to a limited extent, using a car with engine in one end, is adapted to carry about 80 passengers, but is not suited to carry more, and to stop and start, so often as is required; nor can they be reversed at the ends of the route without a turn-table, should it be desired to run the engine always ahead of the passengers. They were not considered suitable for the London Metropolitan line, which is the one that seems to have studied the adaptation of the cars suited to its traffic with care, because they did not supply sufficient power to get up speed as rapidly as required with frequent stops.

As nothing suited to the purpose of conducting the short traffic seems to be in use at present, it may be seen what is required, by an examination of the elements of cost of the present trains in detail. A train to carry 100 passengers consists of the engine and tender of 25 tons, a baggage-car and two long cars, amounting in all to 77 tons, including the weight of 100 passengers, or to 1,550 lbs. for each person carried. The long cars have more than 600 lbs. weight for each person carried.

The attendants, with their wages by the day, are an engineer at $3.48, a fireman at $2.25, a conductor at $3.88, a baggage-man at $2 24, and three brakemen at $5, or a total expense by the day of $17.07. Besides this, the cost by the mile run, is as follows: Fuel, $0.079, oil and grease $0.13, engine repairs, $0.13, car

repairs, $0.10, being a total expense by the mile of 33⅓ cents. It will be seen by the above, that the dead weight hauled per passenger is very great, and this requires an unnecessary outlay for attendance, and also for hauling. If the dead weight per passenger can be reduced, a proportionate saving of labor and fuel and oil, can also be made.

With these ends in view, the following plan is now suggested, for local traffic of passengers residing not more than 20 miles from the city, a distance about equivalent to one hour's ride in the horse cars up town.

The cars proposed are to be a compromise between the horse and the rail cars. They are to carry the passengers, seated as now in the long cars, on seats for two at the side of the car, with a middle passage and end doors. With seats 2½ ft. apart, a car will carry 40 passengers, if made 25 ft. long. These cars are to be set on axles with as wide a base as the curvature of the road will permit, with but little overhang at the ends; and should be fastened together by spring couplers so as to have the train move as one mass. In other respects, they would be modelled like the horse cars. These weigh about 2 tons, and carry safely more than twice the number they can seat. By allowing a ton additional for the framing and bracing of the proposed car, it would then weigh 3 tons, for 40 persons. Assuming now that 200 persons are to be carried, 5 cars and their load will weigh 30 tons. The engine for such a weight may be lighted, and not exceed 10 tons. It should be made to run either end foremost so as to make no delay at the end of the route, by going on a turn-table, but merely switch off, and back to its place at the head of the train, in the direction of the next run. Requiring but little fuel and water for its light load, the tank can be put on the engine frame near to the ground. A train made up in this manner will have great stability, the water and passengers being about 2 ft. nearer the ground than at present.

The total weight will be 40 tons, with power and adhesion sufficient to stop and start quickly, and it will move steadily, since the cars are bound tightly together, and they also have a low centre of gravity. With the same expenses per ton moved as those of the train mentioned above, and assuming that 10 trips can be made in 16 hours, the cost of a 20 mile run will be $1.15 for attendance, and $3.32 for fuel, oil and repairs, or a total of $4.47 per trip, with a capacity to carry 125 passengers through the whole length of the trip. Starting from the city with 200 persons, and leaving part of the load at every station, will give that number as the average through 20 miles. The actual cost of carrying 1 passenger 20 miles will be $3\frac{4}{10}$ cents for train expenses. This is rather less than the rate at which it is stated that cheap passenger trains are now run 10 miles out of London, which is given as 25 cents per week, or 4¼ cents for 20 miles.

Should a part of this saving over present rates be attained, the accessibility, and also with this the value of city suburbs, would be so much increased, to the mutual interest of land-owners and railroads, that even suggestions of what may be done will not be out of place, as calling attention to the subject.

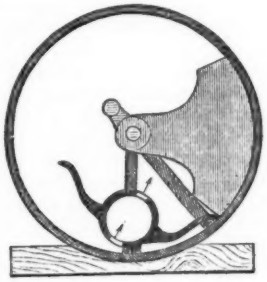
As a large portion of the travelling public is now interested in balloon voyages, it is interesting to know that the generally received opinion, that the temperature of the air decreases uniformly with increase of altitude, is a fallacy. We have Mr. Glaisher's authority for stating that the mean temperature in summer, at 50 ft. from the surface of the earth, is, during evening and night, higher than at 4 ft., and in winter the same relative temperature is always preserved, both by day and night. At sunset, in summer, the temperature is nearly the same for the first 2,000 ft. of ascent; but at night and in winter it increases with the altitude. Thus the phenomena observed near the earth's surface are at variance with those of the ethereal atmosphere beyond.

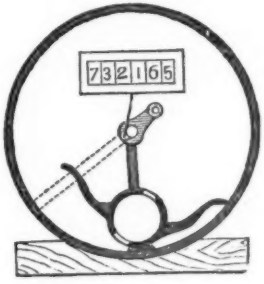
The hydraulic gunboat Waterwitch has been inclined with ballast in the basin at Keyham, to obtain the requisite data for calculating her angles of stability. Thirty tons of iron ballast were placed first on one side of the deck and then on the other, the extreme heel of the vessel being 6 deg.

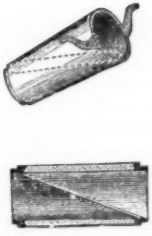
LIQUID METERS.*

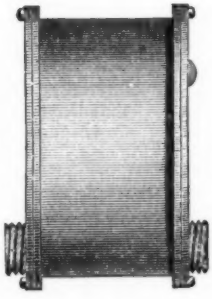
By G. B. MASSEY.

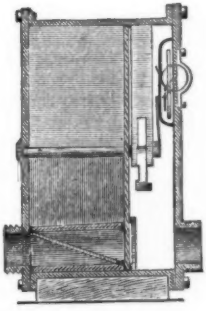
A paper was read on water meters, and the reader, after enumerating many of the different kinds of meters known, and treating upon their respective merits and peculiarities, went into a detailed description of "Massey's central lever water meter." This he considered about as perfect a meter as has yet been invented. It consists of a cylindrical case divided into two compartments or chambers at right angles with its axis. In the larger compartment is a lever or hinged piston as it might be termed, that is a square piston—one side of which is pivoted in the centre of the cylinder, so as to allow it to swing backward or forward, making about three-quarters of a revolution in the case at each vibration. A partition supports the hinge or journal of the lever piston, and through this partition, and parallel to the











line of axis of the cylinder, runs the working valve, which is cylindrical-shaped and opened at both ends, while the division from inlet and outflow of water makes an inclined plane from one end of the valve to the other, the openings into and out of the machine being long narrow slots, one placed on the top of the valve for inflow and the other diametrically opposite in the bottom for outflow. This valve is caused to swing or rock from side to side, so that when the inlet slot opens to the right side on the top, the outlet is opened to the left on the bottom, and *vice versa*. Motion is imparted to this valve by a very ingenious method. In the smaller compartment a weight is hinged on the shaft of the axis of the lever piston, and this is operated by a crank on the same shaft placed in an opposite position to the wing lever or piston. This crank, as the lever piston swings round, catches and lifts the weight until it is just at the

*Paper read before the New York Society of Practical Engineers at the regular monthly meeting March 29, 1871.

end of the stroke, the weight is so adjusted that at the moment it passes its centre of gravity and swinging on the same side as the lever piston, it falls and instantly reverses the valve. The water now entering under the piston forces it over to the other side again, when the weight is lifted and dropped on that side, reversing the openings of the valve and so on.

Mr. G. B. Massey, the inventor of this machine, gave a lucid description of its working parts from drawings on the board; its simplicity is apparent, and the advantages claimed for it seem worthy of consideration.

1*st*. Its compactness and adaptability to all places where the measurement of a continuous stream of water is required.

2*d*. Its lightness and simplicity of construction, as it is composed of but three working parts.

3*d*. Accuracy under large or small flow of water.

4*th*. Its cheapness, as every part can be manufactured by machinery and adjusted by any plumber.

5*th*. The action of the meter must deposit all sand or sediment in the bottom, when it is carried off in the outflowing water. This effectually prevents interference in the accuracy of the machine, which is so often a trouble in meters. Fish can readily pass through (of such size as is ordinarily found into pipes).

6*th*. The power required to operate this meter, like all others, depends upon the workmanship, and under similar circumstances must be less than any double cylinder, as the frictional bearing is less than one-half, according to the amount of water measured and discharged. The arm in an ordinary meter for 1-in. pipe would present a surface of 20 sq. in., and with a head of water of 33 ft. would exert a force of 300 lbs. less the friction, which under proper mechanical construction should not exceed 10lbs. or 1 ft. of the height of water. The weight which operates the valve is so arranged as to reverse or change the flow of water from one side of the measuring compartment to the other at the instant the measure is full, while running fast or slow, and it is impossible for the meter to stop on its centre under any speed or pressure, as is often the case with meters.

FLYING MINES.

From "The Engineer."

One of the most terrible modes of attack and defence known in the art of war is the mine. Here we have a great body of gunpowder confined under the fosse or ditch which troops must cross, or beneath a wall or fort to be destroyed. Fired at the proper moment, this powder charge produces effects which, although localized, are unparalleled in efficiency. Now, were it possible for a besieging army to burrow beneath the town or fortress attacked, and to place a sufficient number of charges of powder in the galleries excavated by the miners, and to explode these charges at the proper time, then would the capitulation or utter destruction of the town follow as an immediate and direct consequence. If the besieged could in the same manner undermine all the advanced positions of the besiegers and blow them into the air, then would the raising of the siege become a certainty. But the work of mining is one of the most tedious and uncertain that armies can execute; and it follows as a consequence partly of this fact, and partly of the great improvements which have been effected in the construction of ordnance, that mining is now less practised in warfare than at any previous time since the invention of gunpowder. Mines are not less effective than they were before, but substitutes for mining in the shape of explosive shells have presented themselves, which are more easily adapted to the wants of armies. Every shell which falls in a town is in effect, to a certain extent, a little mine. But the value of these mines in destructive power is limited by their dimensions and the small range over which their influence extends. Regular mines in the full sense of the term are, however, inapplicable, except on a comparatively limited scale, to the purposes of attack and defence, for various reasons which it is unnecessary to state. But although the construction of an underground gallery beneath a town or camp may be difficult or impossible of

performance, it by no means follows that mines cannot be effectually planted in a town in quite another way. The work to be done consists in placing a heavy charge of powder beneath or near the surface and firing it, and so long as this is done the effect produced will be independent of the means employed in producing it. If we cannot send in the powder to the heart of a town in bags on the backs of men creeping beneath the walls, then let us send it in cast-iron envelopes over the walls. In other words, let us have mines which shall fly in over head instead of creeping in under foot.

The principle which we have thus indicated was first definitely laid down by Mr. Mallet, and although the subject has been suffered to lie at rest for some years, there is no valid reason why it should not be discussed once more. A great deal has been done to prove that, as a matter of fact and not of theory, shells can be thrown to great distances, which shells shall contain charges of powder so enormous that the effect produced by each shell will be disastrous to the party subjected to their attack. Instead of exploding a single mine, or at most half a dozen mines in the course of a siege, it is possible with adequate appliances to plant and discharge mines in every portion of a work attacked, at the rate of 20 an hour, each mine containing as much as 3 cwt. of powder. Under such conditions of warfare it is hardly too much to say that the defence of fortified positions would become a thing of the past, for in the presence of monster mortars and 36 in. shells, fortresses must capitulate or be destroyed. The moral effect alone produced by a few such shells, each a flying mine, would be simply disastrous.

A pamphlet has just been written by Major-General Lefroy containing the story of the 36 in. mortars of 1855–58, which we heartily commend to the attention of all those who may be fortunate enough to obtain a copy. The pamphlet is a reprint from the "Proceedings of the Royal Artillery Institution, Woolwich," and so far not accessible to the general public. It contains a history, succinctly told, of the inception and construction of the two great Mallet mortars still in the possession of the Government, and a "note" from the pen of Mr. Mallet himself, which clears up and explains a few points whose import would otherwise be obscure. No other account of these mortars is in existence, except that contained in a paper read by Mr. Mallet before the United Service Institution in May, 1858. As part of the practice made with them took place subsequently to that date, the paper is necessarily incomplete. General Lefroy supplies the deficiency.

At the time the mortars were designed we were at war with Russia, and above all things we wished to take Sebastopol. The proposal for their construction was brought before Lord Palmerston, and so convinced was he of the value of the shells which they would throw—which he himself christened "flying mines"—that on the 1st of May, 1855, he broke through all official routine and wrote thus to the Lieutenant-General of the Ordnance :—"I am so fully satisfied of the probable success of Mr. Mallet's scheme, that I am willing to take upon myself, as First Minister of the Crown, the full responsibility of carrying it into execution ; and I therefore request that you will, without the slightest delay, take the necessary steps for the immediate construction of 2 mortars upon the plan proposed by Mr. Mallet."

The work Mr. Mallet had cut out for himself was no trifle. He proposed the construction of a mortar which could throw shells, weighing with their charges nearly a ton and a quarter, to a distance of a couple of miles ; and yet that these mortars should be to a great extent portable. The intended weight of each weapon was about 40 tons. We think it a comparatively small matter nowadays to make a dozen guns weighing 35 tons each, and to put them on board ship ; but Mr. Mallet came before the world with his plans sixteen years ago, when the heaviest gun known in the British navy was made of cast iron and weighed less than 5 tons, firing a charge of but 14 lbs. of powder as a maximum. Mr. Mallet proposed to fire 80 lbs. in his mortar, and he did it, too. Built-up guns were unknown ; Armstrong had not yet appeared on the field, Mr. Fraser was but a youth, thinking perhaps less of guns than of anything else connected with engineering. The history of the construction of Mr. Mallet's two great mortars as told by General Lefroy, is an interesting record of the difficulties encountered by an in-

ventor with a great idea, before his time. Obstacle after obstacle presented itself. Mr. Mallet proposed to build up his mortar of a cast-iron base, 30 in. thick and weighing 7½ tons; of a solid wrought iron chamber 70 in. long, strengthened exteriorly by two layers of wrought-iron hoops shrunk on; a great compound ring of wrought-iron built up of hoops; and of a heavy muzzle ring, the whole held together by 6 great longitudinal bolts. We cannot do better than reproduce here the story of the difficulties met with in carrying out the design as told by Gen. Lefroy: "The late firm of Mare, of Blackwall, tendered on May 7, 1855, to supply the two mortars in accordance with Mr. Mallet's drawing and specifications, within ten weeks of the date of order, for a sum of £4,900 each, including the mortar beds; any weight in excess of 35 tons was to be paid for at the rate of £140 a ton. The offer was accepted by the Board of Ordnance the very next day—an instance of promptitude for which we probably have to thank the vigorous interposition of Lord Palmerston. But alas for good intentions and contractors' vows! The mortars were only reported on the eve of completion in March, 1857, nearly a year after the unexpected termination of the war, and ninety-six weeks after the order. They were really delivered in May. The bankruptcy of the contractors and the physical difficulties encountered in the execution of parts of the order combined to produce this great disappointment. They were then partly the work of Mare & Co., partly of Horsfall & Co., of Liverpool, and partly of Fawcett, Preston & Co. The latter did the turning, boring and finishing of the large forgings supplied by Horsfall & Co. Some delay was due to the unsoundness detected in one of the largest of these when it came to be bored. No one who recollects the constant failures in the Royal Arsenal some years later than this, while the use of Yorkshire iron was persisted in, will feel any surprise at such mishaps; on the contrary, it is to the honor of all parties that the mortars were produced at all."

One of the mortars when finished was tried in Woolwich Marshes. The particulars of the rounds fired are very well given by General Lefroy; but it is worthy of notice that not one live shell was fired, o that the effects likely to be produced could only be arrived at by calculation. That they would be enormous is absolutely certain.

We condense the annexed particulars of the rounds from a table given by General Lefroy.

Ranges of shells of 35.6 in. diameter, and an average weight of 2,594 lbs. at 45 deg., for charges bearing given proportions to their weights.

Round.	Weight of shell.	Weight of charge.	Range.	Observed time of flight.
	lbs.	lbs.	yards.	sec.
1	2376	10	373	..
2	2362	20	907	13.0
3	2596	30	1287	17 0
10	2940	40	1531	16 9
11	2940	40	1497	16.1
12	2940	40	1474	15 0
13	2940	40	1444	16.8
8	2660	40	1629	17 3
9	2660	40	1687	17.5
14	2416	40	1700	17.75
5	2986	50	1738	20.0
4	2352	40	1718	19.0
15	2403	50	2120	21.5
16	2373	50	2100	20 0
6	2604	60	2280	24.0
17	2385	60	2323	21.0
7	2548	70	2654	..
18	2400	70	2758	24 5
19	2395	80	2759	23.0

The depth of penetration of these colossal shells in the soft ground of the marshes was remarkable. Gen. Lefroy tells us that "No 1 was found entire at 6 ft. 6 in.; No. 2 was not found on digging down 12 ft., and could not be felt with a 9 ft. probe; No. 3 was not found on digging 18 ft., and could not then be felt with the 9 ft. probe; No. 4 was found broken into 44 pieces, one of them only 5 ft. 9 in. from the surface, but the great bulk of it at a depth of 14 ft. 6 in.; No. 14 was not found on digging 20 ft. 3 in., but was thought to be felt with a 9 ft. probe; No. 15 was found at a perpendicular depth of 19 ft. 4 in., giving a penetration of 28 ft. No others were found, and the Commanding Engineer, Colonel Walpole, estimated that they had buried themselves fully 30 ft. It would have cost about £21 each to recover them, and there they remain, to astonish, perhaps, geologists hereafter."

Lack of space prevents us from dwelling further on the results obtained. Suffice it to say that all Mr. Mallet proposed to do, he proved himself able to accomplish, as far as the powers of the mortars and shells went. But, owing to the im-

perfect appliances for forging heavy masses, only which were available until a very recent period, portions of the mortar gave way; and to the fact that no pebble powder was to be had, although Mr. Mallet proposed its use, much of this failure was due. The mortar was several times repaired at a comparatively small cost, but General Peel had succeeded Lord Palmerston in office, "a king who knew not Joseph," and he refused to sanction further expenditure; and so the great mortar stood in Woolwich Marshes till 1869, when the bed being decayed the mortar was blown down at the small charge of 12s. 10d. for gun cotton, we suppose to avoid the chance of its falling on some little boy and hurting him; only £150 worth of valuable iron work in the base being ruined at the same time. Who is responsible for this piece of vandalism we do not know.

That 36-in mortars, as proposed by Mr. Mallet, will yet play an important part in warfare, we have no manner of doubt. Their construction would be a comparatively easy matter in the present day. Let us hope that they will be used when the time comes, but not against us. We cannot conclude this slight sketch of General Lefroy's admirable paper better than with the following quotation from its pages:

"It is almost idle to speculate on the effects of shells weighing from 2,300 lbs. to nearly 3,000 lbs., and with bursting charges of 487 lbs. to 405 lbs. The experiment was not tried, and in the interests of humanity we may hope that it never will be; but few will doubt that if the mortars had been completed in time, and Lord Palmerston's intention to send one to the Baltic and another to the black Sea been carried out—and designs for mortar rafts had been actually prepared by Mr. Mallet—it would have been perceived that a new power had entered the European arena. Those heroic soldiers who prolonged the defence of Sebastopol against a *feu d'enfer* had no resources which could have prevented all the defences on the south side, up to Dockyard Creek, from being devastated by a succession of such mines sprung within them, or those on the north side, including the North Fort and Battery No. 4, from sharing the like fate, without the exposure of the mortar vessel to any destructive fire. The casemates of Cronstadt, like everything else of masonry, probably, which the hand of man has put together since the Pyramids, must have crumbled under bolts as irresistible as those which '*fulminantis magna manus Jovis*' discharges; bolts which, according to Horace, only the soul of the upright man can defy."

NEW PAPER-MAKING MATERIALS, AND THE PROGRESS OF THE PAPER MANUFACTURE.

By L. P. SIMMONDS, Esq.

From "The Artizan."

This subject is one of much importance, in which we are all, more or less, deeply interested. There can be no question of the value of paper as a means of diffusing knowledge, awakening thought, calling forth invention, and civilizing the world. It is the handmaid of all arts, of all sciences, and of all trades. Both in an educational and a commercial point of view, an extensive supply of paper, at moderate prices, is of national interest. The laws of supply and demand will, indeed, regulate the question, but discussion and circulation of opinions may result in extended benefit to the paper-maker as well as to the reading and writing public.

The technical question of what is paper, what are the materials of which it is composed, may well be raised, for it led to a trial, some years ago, between the Excise and a paper-making firm, the Attorney-General *v.* Barry. In the edition of "Johnson's Dictionary," published about the middle of the eighteenth century (1755), paper is defined as "a substance on which men write and print, made by macerating linen rags in water, and then spreading them in thin sheets." "Webster's Dictionary," of our own day, enlarges the list of materials, and describes it as "a substance in the form of thin sheets, or leaves, intended to be written or printed on, to be used in wrapping,

etc., and made of a pulp obtained from rags, from straw, from bark, or like materials, pressed and dried."

An historical fact, which was announced 20 years ago, by Dr. Crace Calvert, may be again noticed here. It is that paper, made from the papyrus plant, had lasted from 1,822 years before the Christian era to the eighth century. Egypt was invaded by the Arabians and her trade destroyed. It was then, for the first time, that cotton paper was first imported from China by the Arabians, who, 2 or 3 centuries afterwards, supplied us through Turkey. The manufacture of their flax paper was so successful, that cotton paper was completely laid aside until the commencement of the present century, when once more it expelled from the market the linen paper.

Our word " book" is said to have come from the Gothic word for the birch-tree, some part of which, probably the liber, or inner white rind between the bark and the wood, may have been the most convenient substance which nature has furnished in the northern parts of Europe for portable documents. Other substances than of vegetable origin may be written or printed on, of which we have familiar instances in the present day, in our slates and stone tablets, copper and steel plates, parchment and vellum, gelatine paper, silk play-bills. In olden times, characters, too, were engraven on stone, or impressed in clay, dried and hardened, as the Babylonian bricks, boards of wood covered with wax, plates of ivory and metal, and the leaves of palms were used. The Chinese, Japanese, and Indian papers are made without rags, consisting chiefly of bamboo, the paper mulberry, and other macerated barks and fibres, and their celebrated rice paper, so long a mystery, is now known to be made from the cellular pith of the *Aralia papyrifera*.

Among the influencing causes for the greatly increased demand for paper are the removal of the excise duty on manufactured paper and the stamp from newspapers, the extended number of daily and other journals issued at a cheap price, and the large editions of these called for, owing to the eagerness to obtain intelligence of the progress of the unfortunate war now raging. The increasing commerce of the country must not be lost sight of, and the extensive home and foreign correspondence resulting therefrom, some 700,000,000 letters passing annually through the post. Educational progress also leads to more writing, reading, and book-printing. We have also to remember how many other uses paper subserves, as wrapping material, for cardboard, *papier maché*, *carton pierre*, etc.

Building paper now forms a regular article of commerce in the United States, and more than one public company is doing a large business in it. It is used on the outside of frame buildings, and under shingles and floors, to keep out the cold, and on the inside instead of plastering. It is said to be both warm and cheap. Paper tiles are also used in Saxony for roofing sheds, stables, and barns; and paper collars and other articles of dress have long been in use.

When we consider that 550,000 tons of cotton, 125,000 tons of jute, and 130,000 tons of flax and hemp, were imported and worked up in 1869, besides 53,000 tons of home-grown flax, one would suppose there ought to be a great deal of the waste of these fibres available for the paper-maker. But among the minor tendencies of industries few are more noteworthy than that shown in the increased utilization of waste materials. As competition becomes sharper, manufacturers have to look more closely to those items which may make the slight difference between profit and loss, and convert useless products into those possessed of commercial value.

Our manufacturers have not been slow to appreciate this truth, as is shown in more than one branch of trade. Thus, the refuse blowings and droppings from the spindles and looms of cotton-mills, which were formerly available for the paper-maker, are now found to possess a high textile value, and form the basis of a distinct branch of trade. Millions of pounds of this waste cotton are now used annually in the fabrication of wadding, common carpets, twine, etc. There are a hundred opportunities among the staple industries of the country to secure an equal economy and profit, by turning to proper uses substances now disregarded and thrown away as waste.

In the manufacture of paper, as well as in all other mechanical industries, there has been great progress made, even in the last half century. Chemistry and me-

chanics have each contributed their part. The former has afforded us improved methods for washing, bleaching, and coloring the paper stock, which must yield a different product from what was made by the ancients. The mechanical improvements, too, have been many, both for boiling and running out the pulp. The use of ultramarine, which was at one time almost as valuable as gold dust, has been so extended and cheapened by the labors of the chemist, that its artificial manufacture must be regarded as one of the triumphs of modern science.

Chemistry has also taught us that the cellulose of all plants is the same as that contained in rags, and that, in fact, the fibre of some plants will give us a paper that cannot be made from rags. Not all plants, however, are adapted to the making of paper. Much depends upon the bark, membrane, and fibre, and there is a difference in the purity of the cellulose, in various plants. Chemical tests also show a modification in the fibre of plants. The cellulose of cotton yields a blue color immediately, with tincture of iodine; that of flax does not turn blue until an acid has been added, and hemp requires both acid and considerable time before the blue color makes its appearance. These reactions point to the presence and absence of starch and glucose in different species of plants.

The removal of the excise duty on paper, which took effect in the year 1861, renders it difficult to ascertain with any precision the quantity of paper now made in the kingdom, but we may form a fair estimate by looking at the progress under the duty rate, and judge of the advance from the incentives and stimulus to increased production. The following are official figures of the quantity of paper charged with duty :—

	lbs.
1842	96,693,399
1852	154,469,211
1861	229,502,864

From which we may fairly estimate the present production at 300,000,000 lbs.

Our shipments of paper scarcely keep pace with the increased production and home consumption, which may be attributed to foreign competition, and the colonial paper mills now established in Canada and Australia. The exports are officially given as follows of British paper :—

	Quantity. cwt.	Value.
1860	112,514	£450,589
1865	141,075	447,741
1869	214,416	591,436

The exports and consumption compare as follows, in pounds weight :

	Exports.	Consumption.
1849	5,966,319	126,166,341
1859	20,142,352	187,684,847
1869	24,014,592 (estimated)	276,000,000

In 1869, our export of paper of different kinds, including paper-hangings, was valued at £727,071. The quantity of foreign-made paper received has been annually increasing of late years. In 1869, 412,900 cwt. were imported valued at £690,547, of which 49,926 cwt. were re-exported. The following are the imports of foreign made paper of all kinds in the last three years, in cwt :—

	1867.	1868.	1869.
Printing or writing	174,429	177,220	169,275
Other kinds	151,925	193,387	243,626
Paper-hangings	7,753	5,660	4,435
Total	334,107	376,267	417,306

Besides these foreign figures, we have to consider the quantity used for paper-hangings. The home consumption under this head I can form no estimate of, but give the exports. In 1858, these were stated at 15,000,000 yards, valued at £74,649; in 1869 the official returns gave the quantity of paper-hangings exported at 46,617 cwt., of the value of £132,635.

The paper-makers' licenses, granted during the time of the duty, afford some idea of the briskness of trade, and the paper-mills at work. I find the number of mills rose from 408, in 1785, to 800, in 1829 (the highest number reached). They then declined annually until 1852, when there were 400, at which, with variations of some 8 or 10, the number has since stood. The licenses granted in 1869 were 326 in England, 60 in Scotland, and 22 in Ireland, but all the mills were not at work, and within the last year there have been still further reductions in the number. The "Paper-mills Directory" for 1871 gives the number of paper-mills in work-

ing order in England, in 1870, at 274, besides 12 mills not working, making a total of 286, against 290 in 1869. In Scotland there were 63 mills at work last year, against 58 in 1869. The larger number of paper-mills make brown, cartridge, and such like papers; in England, not more than 100 make printing, news, etc.

If we look at a few of the latest figures regarding the publishing and printing trades, we shall see how important is the question of paper to supply the demand. There are at the present time more than 1,400 newspapers in the United Kingdom, of which 110 are daily, of these 61 are published at one penny, and 34 at one-half-penny each. The mgazines and reviews number 626. The quantity of paper which these require, it is impossible to calculate; but when we find that one London daily paper asserts its average daily circulation to be upwards of 190,000 copies, and if we assume the other London dailies to have each but half this circulation, we can form an idea of the enormous demand for paper, even in the metropolis. Besides the political journals, some of the literary, religious, sporting, and other publications, have very large circulations. But we have also to take books into consideration. According to the "Publishers' Circular," last year there were 4,656 new books and new editions published in Great Britain. In the United States about half this number are issued, and in Germany three times as many. This is independent of the large number of newspapers and books issued in various other parts of the globe. The make and consumption of paper in the United States are nearly as large as our own.

In 1869, we exported 59,291 cwt. of books and imported 11,463 cwt., and the progress in 10 years is shown by the figures of 1859, which were 33,915 cwt. exported, and 6,520 imported.

The price of rags mainly regulates the price of paper, for these are the mainstay of the paper-maker, although now supplemented to a small extent by crude vegetable fibres. The comparative scarcity of rags and kindred substances has rendered their supply, as a main article for paper-making, more and more inadequate, while the importation of esparto fibre from the Mediterranean countries has likewise failed to meet the augmented demand.

The import of foreign rags suitable for paper-making has increased in the last 10 years about 50 per cent. For 20 years it averaged about 10,000 tons. In 1858, it was 11,379 tons, value £246,133; in 1869, it was 17,000 tons, value about £300,000. The aggregate quantity of rags annually collected in the kingdom, with those imported, may be taken at 70,000 tons weight, worth at least £1,500,000. It takes 100 tons of rags to made 70 tons of paper. Notwithstanding the rags produced by our population of 30,500,000 inhabitants, added to the large quantity of jute, bagging, linen and cotton wrappers, old sails, cordage, etc., it will be seen that we are largely dependent on foreign supplies of waste materials for our paper-mills. Linen rags have declined in price from £22 18s. per ton, in 1866, to £19 12s., in 1869, and cotton rags from £13 19s. to £12 4s.

The average value of the rags and other paper-making materials imported in the last 2 years was about £110,000. The quantities are shown in the following return, in tons :—

	1867.	1868.	1869.
Linen and cotton rags.....	18,407	17,860	16,980
Esparto	54,512	95,828	86,334
Other vegetable fibres.....	562	52	1,084
Other materials for making paper....	794	615	1,702
Tons.....	74,275	114,355	106,100

Since the discovery of a method of separating ink from printed paper, old newspapers and old books have entered largely into the paper-makers' material. And the lesson of economy should be learnt, to save for market the waste paper, instead of kindling fires with it and casting it to the winds. Let frugal housewives take a hint, and add the present wasted hundredweights of old paper to the great civilizing agent of the present day.

A correspondent of mine well observes: "For many years it has been pointed out, in every possible way, that an endless variety of cheap materials exists in British tropical dependencies, admirably suited for paper-making, but the ever-recurring difficulty is, not where to get it, nor even what to get, but how to induce any one to bring it, or, if brought, how to

induce any one to be the first to use it. This want of spirit is the dead weight which presses so heavily on the paper-manufacturer."

Owing to the increased demand, and the enhanced price of rags, it has been found necessary to employ other substances for mixing, such as, for instance, straw, esparto grass, and wood. Generally speaking, and especially as regards the grasses, these auxiliary pulps, however, do not fall very far short in price of the rag-product, and thus, while by such admixtures the immediate demands are met, the cost of paper remains high, and acts as a check on that expansion of the paper-manufacture, which is one of the greatest and most urgent requirements of the times.

Wood pulp, chemically produced, although undoubtedly good as to quality, labors under the disadvantage of being too dear; but its production by mechanical agency, which is much less costly, may now be considered as brought to great perfection by means of improved machinery, amongst which Voelter's system claims an undoubted superiority, at any rate, in localities where the raw material is abundant enough to afford supplies for their great converting capacity, and its action is facilitated by a sufficiency of water-power. Under such conditions, each one of M. Voelter's engines of the ordinary size is capable of producing 17 cwt. of pulp daily, at a cost varying in proportion to the nature of the motive power employed, the price of the raw material, the facilities of transport, the rate of wages, and other contingencies.

In all these respects, Sweden, according to a detailed report of Mr. Gustaf Josephson, offers peculiar advantages. The supply of soft pine wood, perhaps the most suitable of all for the manufacture of paper-pulp and pasteboard, is there practically unlimited, and obtainable at a price of 1½d. to 2d. per cubic ft., whereas in Germany, where a number of such works have been in existence for some time, and have supplied English markets with their produce, which is, however, mostly of inferior quality, the same material is worth about 3d. per cubic ft. on an average. Aspen wood is likewise plentiful and cheap in Sweden.

There are now about 160 of these wood-pulp machines at work on the Continent. Some of those in Germany and Belgium, and about 30 of those situated in the Scandinavian countries, where material is abundant, send their pulp to England as a paper material.

The first mode of preparing wood-pulp from the pine and other white woods, was to reduce it into thin shavings, which were soaked in water for 6 or 8 days, and then dried and ground into powder by a corn or crushing mill. This powder was mixed with rags, so as to make a pulp, and the ordinary operation of paper-making was then proceeded with. The principal defect of this material was the shortness of fibre.

The preparation of wood-pulp has not hitherto been sufficiently successful to make it rival rags, esparto, or straw. Further experiments may, however, go far to remove the present defects.

Esparto, as it is called in Spain, and alfa on the African coast, is a coarse, rushy grass, which has long been used as a fibrous material for rough yarn and cordage, and more than 30 years ago was recommended as a paper-making material, but was only brought into extensive use about 16 years ago, by the persevering efforts of Mr. Thomas Routledge. No material alteration in the machinery or apparatus is required for working esparto, and much less power is necessary. According to a practical authority,* the successful working of this fibre depends mainly on the careful and proper adjustment and strength of the chemicals employed. The quantity of soda-ash required for neutralizing the gummo-resinous matters in the fibre, so as to admit of its being made into pulp, is very large, though not so great as is required for straw; and the fibre, unlike rags, never having before been subjected to bleaching or other chemical treatment, also requires very much more bleaching powder to bring it to color suitable for printing paper. The quantities required are from 5 to 6 times as much as for cleansing and bleaching the coarsest rags.

In a late circular of Messrs. N. W. Chittenden & Co., fibre brokers, they state that, "during the past year, numerous small importations of various descriptions of fibre have occasionally been made, and ready experiments have been afforded to

*Mr. W. H. Richardson, on the Paper Manufactures of Northumberland and Durham.

test their capabilities, yet none has been found as a practical substitute; and during the past 12 months upwards of 93,750 tons of esparto have been imported into the United Kingdom, and although there has been but little falling off in the importations of other material previously used, the price of esparto still keeps at about £10 per ton. What effect this may have upon manufacturers who have been at a heavy expense in erecting machinery to work this article, when it was supposed that any quantity could be had at £6 or thereabouts, with but slight fluctuations in value likely to occur, we cannot say; but it seems an astonishing fact, that although the consumption of paper has been greater than ever, and that most raw materials from which it is produced have risen, our makers have not combined to raise the price of their production in proportion.

A correspondent, reading the discussion which took place last year, in the "Standard," on paper materials, sent me specimens of pulp which he had prepared in Jamaica, under difficulties, from various substances, such as the bamboo, different fibrous plants, simply crushed and macerated, and wood pulp from trees of large growth. The fibrous plants of Jamaica, he observes, are numerous, and deserve a greater amount of attention, but hitherto nothing of a substantial or permanent character has been done practically. The Jamaica papers have since taken up the subject. A recent "Kingston Morning Journal" has the following editorial remarks:—"It seems, from all we can gather, that there is a market for our fibres, and such material as they convert into pulp, if only we would set to work to produce them. There is no lack of material for this purpose. From one end of the island to the other it abounds, of various kinds, and of various qualities. It is really pitiful to ride about the country, and see the acres of penguin that uprear their heads and spread themselves about as they can find space, preventing all other vegetation from thriving, while it is itself practically of no use whatever, and may be regarded as an encumbrance of the ground. What a mine of wealth we have in these same penguin plants, if only people would take the trouble to set about to extract it. Years ago, the matter was talked over, and it was then set forth that the fibre is abundant, is strong, is of excellent quality for manufacture into certain kinds of cloth and cordage, while the material is as 'common as dirt' in the country. It is a pity that so little—indeed, nothing beyond the trying of a few experiments—has ever been done to turn it into practical and useful account. Besides the penguin for the production of fibre, there are the plantain and the banana plants. There is not a peasant or small settler who does not cultivate them pretty extensively. Travelling through the mountain districts, the very first thing to apprise the belated traveller that he is getting within the circle of humanity, is not so much 'the watch-dog's honest bark, baying deep-mouthed welcome,' or unwelcome, as the sight of those graceful plants, waving their leafy wings in the soft night air that plays around them; and, when the village is reached, there is not a cottage but is surrounded by them; there is not a garden in which they do not abound. Then there are the fields, or 'grounds,' that lie beyond the confines of home, on the higher lands, in which plantain and banana plants are to be seen also growing abundantly. These require little or no cultivation. They propagate themselves by means of the suckers that shoot out of their roots, and, except occasionally pulling the grass from around those roots, the trouble they occasion the husbandman is of an infinitesimal character. The plants abound in fibre of a coarse character, that would be valuable in the manufacture of cordage, while the pulp might be converted into paper of a coarse description. All the use that is made of the plant at present is to cultivate it simply for the sake of its fruit. The other portions of it are thrown down, and lie on the ground and rot. There is some singular fatality attending this country, that so much that is useful, so much that is really valuable, is allowed to grow up and then to rot, when it might so easily be converted into money."

The paper-yielding stems of the plantain and other indigenous plants have been too long neglected. Useful and tough kinds of paper have been made from them. Simple pressure between rollers and washing would appear to be sufficient for the separation of the fibres of most of them.

A Jamaica correspondent sent me by the last mail a copy of a daily paper, which reports that the Governor, "Sir John Peter Grant, is turning his attention to the development of the fibrous wealth lying latent and running to waste in this island. In plainer language, his Excellency thinks there is money to be made by preparing for market the numerous varieties of plants growing without cultivation all over the country, from which fibrous materials may be extracted, for the manufacture of cordage, textile fabrics, and paper; and we learn that he is about to bring to this country a person experienced in the extraction of fibres from the plants containing them, if not for the further conversion of the materials so evolved into manufactured articles. At present, we do not go so far as to insist on the manufacturing part of the project, but we would content ourselves just now with an impetus, such as it is said Sir John contemplates, to the growth and preparation of the raw material for the purposes of the manufacturers of Manchester, Glasgow, and other towns and places in the United Kingdom. We are not so ambitious as to 'despise the day of small things.' Therefore, for the present, at least, we should be quite satisfied to witness the shipment of a few tons of raw material spoken of, by way of a beginning to a new industry which, we are convinced, if followed up with spirit, is calculated to provide a handsome living, if it do not lead to affluence, to such persons as may engage therein, provided that they set about the work understandingly, and carry it on skilfully, and at the lowest possible cost. Nor does it appear to us that any very elaborate process, involving complicated and costly machinery, is absolutely necessary for the purpose of separating from fibre-producing plants, such as we have in such luxuriant abundance in the island, the ligaments, which form their strength and real substance, from the feculences which keep them together in a state of cohesion. Now, the Jerusalem dagger, as well as the common dagger (this I believe to be *Yucco gloriosa* and *Aloefolia*), grow luxuriantly all over the island. In regard to the latter, it is too common to render necessary one word about it. The other variety is not so well known. The leaf is more soft and pliable, and seems to us to be more adapted to the manufacture of cordage, and perhaps for textile fabrics, than the better-known kind. We can assure our readers—and we now address ourselves more particularly to those abroad, who are in any respect interested in spinning and weaving—that the fibre of the two plants we have already named require no bleaching—at least it seems so to us; for immediately as it is cleaned, washed and dried, it is as white as the best bleached linen thread, and much whiter than the printing paper on which this article has been written. Nor this alone. It is as fine as the finest silk as it comes from the worm, tough, and elastic. Unlike the plantain fibre, which breaks if made into a knot, it is tenacious, and can bear any complication of knots without snapping. This is one of the greatest desiderata in all fibres, whether for cordage or textile purposes. Then, if we mistake not, whatever substance is suitable for cordage and woven fabrics is equally suitable for manufacture into paper, with this advantage, that, for the latter purpose, the waste and refuse, embracing short, broken fibres, may be used with equal benefit to the long, sound fibre employed for the other purposes named. And as there has for many years existed an outcry about the scarcity of rags, which the wars now raging will serve to enhance, from the demand for lint and bandages for the wounded, it seems to us that we have hit upon a plan—which, by the way, we did as long ago as the time of the Crimean war—whereby the wounded may be benefited, without in the least inconveniencing the paper manufacturer. We may add to this, that this latter will be able to turn out a superior article, because he will have for a stock a raw material much stronger than the old rags he has been in the habit of employing in his manufactory. We have already alluded to the marked whiteness of the fibre of the dagger. In this, as well as in its greater flexibility and tenacity, it is far superior to the fibre of the plantain or banana of any description, which would require considerable bleaching for either paper or any of the textile fabrics."

The bamboo is not a new paper material, although it has only recently been introduced into this country for that purpose. Much of the common Chinese

paper is made from it, as may be seen described in Herring's work on Paper, p. 31. The American paper-makers have for some time drawn supplies from British Guiana, Jamaica, and other parts of the West Indies. In the paper which I read before the Society 2 years ago,* I called attention to what the Americans were doing with bamboo as a paper material, and this seems to have drawn attention here to this gigantic grass.

During last year, some supplies of a very excellent new material were imported from the Portuguese settlements on the west coast of Africa, where considerable quantities may, it is said, be obtained. It is the fibrous bark of a Sterculiaceous tree, the baobab (*Adamsonia digitata*), and, from its tough fibrous net-work, it would in quantity be very valuable to the paper-makers. It is not a tall tree, but attains gigantic dimensions in growth, being described by travellers as a "vegetable monster," and "behemoth of the forest," being frequently 80 or 90 ft. in circumference. Livingstone asserts that nothing short of boiling the tree in sea-water could possibly destroy its power of vitality. Constantly barked by the natives, the tree nevertheless retains its full vigor, and a removal of the very core or centre of the stem would not, according to that traveller, affect the existence of the tree; and "the reason is," to quote his own words, "that each of the laminæ possesses its own independent vitality; in fact, the baobab is rather a gigantic bulb run up to seed, than a tree." This tree or an allied species (*Adamsonia Gregorii*) is found in the West Indies and North-Western Australia. The bark fetches readily here £14 to £15 per ton. This bark furnishes indestructible cordage, and a close thread used for cloth and ropes. Ropes made from it are said to be so strong that there is, in Bengal, a saying, "as secure as an elephant bound with baobab rope."

At a late meeting of the Scottish Paper-makers' Association, the chairman urged that the attention of makers should be turned to the introduction of other materials to cheapen the cost of production, or to increase the percentage of paper yielded by the materials now in use. Wood-pulp might soon be more generally used, as, from recent information, there were means lately discovered, and soon to be patented, whereby the fitness of this material would be greatly improved, and its price be exceedingly moderate. An inquiry into the practicability of growing a vegetable fibre at home, as a substitute for esparto, was held by several Scotch paper-makers with the Chamber of Agriculture, but no definite conclusion was arrived at. The general opinion, however, was, that straw was the cheapest and best material that could be had; but great difficulty exists in obtaining large supplies, owing to the lease stipulations requiring it to be consumed on the farm. The market price of straw here being also £6 per ton above what it is in Sweden and Belgium, it can be imported from those countries cheaper than it can be bought here.

The vacoua sugar bags, which are made from the tough longitudinal fibres of the leaves of the *Pandanus utilis* and other species of the screw pine, are a useful paper material. Three millions of these bags are made annually in Bourbon, and a large number also in Mauritius. The leaves are cut every second year, and each plant yields enough for two large sacks or bags. The leaves yield paper of good quality, light and strong.

In Australia, attention is being directed to the utilization of local materials for their paper-mills. At the recent Intercolonial Exhibition at Sydney, in September last, a bronze medal was awarded to the Paper Company for its brown, printing, and news-printing, made at their Liverpool mill. The brown paper was chiefly made from refuse New Zealand flax; the printing is used by the local journals. The hand-made papers, shown by Dr. Mueller, of Melbourne, proved from what a great variety of vegetable fibres paper can be made; but the difficulty to be conquered is commercial—not mechanical—the cost of reducing much of the fibre into paper being prohibitory.

A select committee of the House of Assembly of South Australia reported, in August last, that thousands of tons of material, equal to any demand, and suitable to the manufacture of fibre, is growing extensively in various parts of the colony, and a large proportion on the Crown lands, while the cutting of it does

* "Journal," vol. xvii., 1869, p. 175.

not destroy the plant, but tends to improve it. The committee report their opinion that a new and valuable industry might be opened up, not only to supply the colony with material useful for various manufactures, such as hemp, rope, and paper, but there would also arise a very large European trade. The committee, therefore, recommend that a bonus of £2,000 be offered by the Government for the first 500 tons produced in the colony.

Dr. Mueller, in an elaborate article on the barks, foliage, grasses, rushes, etc., of Australia suited for paper-making,* remarks that forest regions and coast lines, swamps and flats subject to inundations, should prominently yield the material for the factory; for, on open pastures or otherwise occupied tracts of country, even paper material cannot be harvested for an unlimited period, at the expense of the soil, with impunity. In factories situated in the vicinity of forests, the soda expended in paper manufactures might be profitably regained by evaporation of the ley, and crystallizing it with coal or sawdust. In viewing (he adds) the immense supply of various kinds of paper material here cheaply available, there is no reason why they should not form, closely pressed, an article of export probably less inflammable than rags; and, still more, it may safely be anticipated that, together with the consumption of rags in local factories, the new articles indicated will largely enter into the fabrication of paper, the product of Victorian industry.

I have not thought it necessary to take up the time of the meeting by an enumeration of all the Australian materials on which Dr. Mueller has experimentalized, with more or less success. Many of these have been repeatedly brought under notice, others are new; but I have specimens of various papers made from them here, for the inspection of those interested. These papers have not been subjected to chlorine, or drawn through size.

In the reports of the jurors at the New Zealand Exhibition of 1865, it is stated that New Zealand produces a number of fibrous plants and grasses suitable for the manufacture of paper, a branch of industry which must, at some future time, become an important one. The bountiful supply of pure water with which almost every portion of the colony is blessed, and the facilities which exist for the erection of mills to be driven by water power, combined with the abundance of paper-making material, which grows in profusion throughout the colony, constitute New Zealand as *par excellence* a favorable country for the production of paper for the supply of this and the other Australian colonies. With regard to paper-making material, the *Phormium tenax* must again occupy the first place.

Not only is the fibre admirably suited to that purpose, but it is the more valuable, inasmuch as the refuse particles of fibre, after its preparation for spinning, are available for the manufacture of paper. In the event of the cultivation of the *Phormium tenax*, there will always be a large quantity of damaged, and what would otherwise be waste leaves, which would be valuable to the paper-maker. Forty years ago, paper was made of it to print an edition of a work by Mr. John Murray, of Edinburgh, on the plant and its uses. The peculiarity of this paper is its tenacity, which property should make it valuable for documents and printings to stand a great deal of wear and tear. No better paper could be used for bank-notes, or for the printing of valuable standard works.

Many of the native grasses of New Zealand are sufficiently fibrous for the manufacture of paper, and the profusion in which they grow on almost every variety of soil, and under every condition of the climate, is an additional reason why efforts should be made to utilize them. One variety of grass in particular claims attention, from its resemblance in many important features to esparto; this is the "snow grass" of the tussocky grasses of the colonists (*Schœnus pauciflorus*, Hooker), which grows rank and luxuriant at high elevations and on barren soil, in the interior of the Middle Island. Experiments have been made at Dunedin as to the paper-making qualities of this grass, and the trial was sufficiently satisfactory to establish its value for the purpose. But while I direct attention to these paper-making materials, I fear Australia is too far distant to be thought of for any extensive supply of raw material, and we must look to nearer quarters, such as the shores of Northern and Western Africa,

* "Journal of Applied Science," August, 1870.

Brazil, Central America, and the West India Islands.

Seven or eight years ago, in a work which I published on the utilization of waste substances, I suggested that the woolly fibre adhering to the hulls of the cotton seed might be economized in the manufacture of paper, and I am glad to find that this, like very many other hints thrown out, has since been carried into practice.

At the last meeting of the British Association, a paper was read by Mr. Thomas Rose, of the firm of Rose & Gibson, of Sankey Mills, Earlstown, on the further utilization of cotton seed, and especially by converting the short cotton fibres adhering to the husk of the herbaceous cotton, and the husk itself, into paper. The seed yields, in round numbers, 50 per cent. of kernel and 50 per cent. of fibrous husk. The kernel yields about $\frac{1}{3}$ crude oil and $\frac{2}{3}$ cake. The fibrous husk gives an average of 30 per cent. pure fibre. The process of operating is this, the cotton seed is fed between a pair of rollers, running at differential speed, and not quite in contact. This cracks the husk or shell, and allows the solid kernel to fall out and be easily separated. A system of riddling further separates a great deal of the dry, broken husk. After this it is boiled in caustic soda, in a revolving boiler, by which means much of the remaining husk is got rid of, and final washing so completely liberates the cotton that it is ready for bleaching. After this process, it is reduced to pulp, and converted into paper. Supposing this to prove a success commercially, of which Mr. Rose (who is now in America on the subject) appears to be more sanguine, it will further utilize a waste product on which I have often spoken in former years in this room, and add something to the wants of the paper-maker as regards raw material.

In a late number of the "New Orleans Picayune" (Nov. 10, 1870), I find an article giving elaborate statistical calculations about the value of the cotton seed and its subsidiary products; but I am a little sceptical as to American estimates and figures, particularly when the money value of the oil, oil-cake and ashes of the hulls, as a fertilizer, are set down at the large sum of £11,000,000 sterling, or equal to $\frac{1}{4}$ of the value of the incoming crop of cotton. The quantity of cotton seed from an American crop of 3,000,000 bales is represented to be 2,250,000 tons. Now, sharp as our American cousins are in turning matters into money, they do not appear yet to have thought of utilizing the fibre. If this is all woolly seeded cotton, the weight of seed spoken of ought to yield about 300,000 tons of pure fibre, worth, to paper-makers, not less than £7,500,000. And this is quite irrespective of the bark of the stem of the cotton plant, which I have not yet heard is economically used.

Looking at the utilization of this small cotton seed fibre, I see no reason why another material should not be available, in the fibrous husk or covering of the betel nut of India (*Areca catechu*), which is in such general use throughout the East. The fibre has a soft and cotton-like feel, and is capable of being spun into twine. Immense quantities of these husks are now thrown away, and, as a paper material, they ought to be collected in large quantities and at little cost. From Ceylon, about 70,000 cwt. of these nuts are shipped annually, and large quantities from Penang, Sumatra, and Travancore, and from other quarters there are also large exports.

One material has been again brought into notice, the New Zealand flax lily (*Phormium tenax*). Twenty-five years ago it was shipped from the colony as a paper material in solid lumps, to lessen freight. The paper obtained from it is the strongest of all. The subject from that time to the present day, has been one of almost constant discussion. The readiness with which the large richly-fibrous leaves can be turned into pulp for a very substantial paper, entitles the plant not alone to consideration, but also the fact that it may be permanently established with the greatest ease in any swampy ground.

The leaves of many palms, but chiefly of the dwarf palm *Chamærops humilis*, *Phœnix spinosa*, and other species, have lately been imported for paper-making, and are found useful if well separated from the leaf-stalk, which is hard, stiff, and brittle.

A patent has lately been taken out for applying the creeping stem of the antidote cocoon (*Feuillæa cordifolia*) as a paper material. This is a cucurbitaceous perennial scandent plant, climbing on the highest trees, very common in Jamaica.

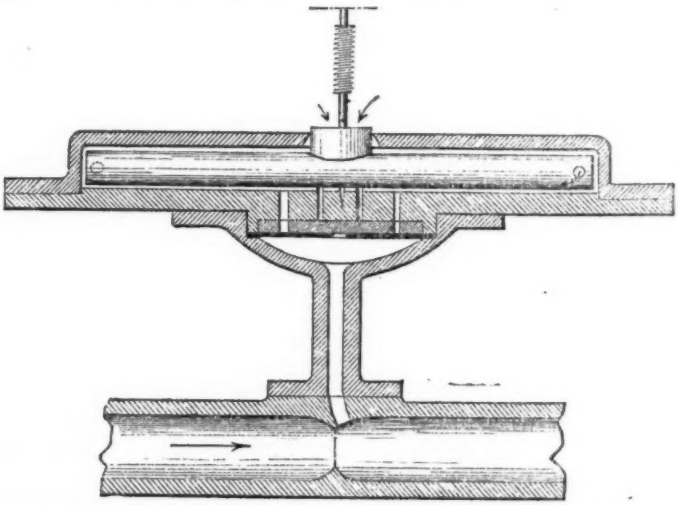
It has been well remarked that it is from a careful observation of the laws of vegetable growth and decay that man has been enabled to take advantage of many of the beautiful vegetable products that lie scattered about in luxuriant profusion, and in proportion to the pains he takes to observe the laws of nature, and the judgment he displays in applying this knowledge to scientific or useful purposes, so are the results beneficial to the community at large. One man looks, perhaps, at the chemistry of vegetables, another merely at the physiology, while a third considers it useless to waste time with such abstruse studies, and inquires merely what is the mercantile value of fibrous substances, and how cheaply they can be brought into the market. Now, all these inquiries have their relative importance.

In this superficial inquiry on paper-making materials, I have merely touched upon a few of the more prominent, without going into practical details, which can best be supplemented by those present who are specially engaged in the manufacture. The subject will not have been introduced in vain if any of the facts or suggestions I have brought forward shall result in benefit to those who are more specially interested in the manufacture of paper.

A NEW WATER-METER.

Translated from "The Polytechnisches Journal."

Flowing water may carry air along with it, either in consequence of motion through air or contact with it. The maximum effect of this kind occurs with a stream of the form of the *vena contracta*, in which the quantity of air conveyed is in proportion to the quantity of water discharged.



The apparatus of J. A. Muller, of Amsterdam, shown in section in the figure, is based upon this fact. The stream of air induced by the flowing water is employed to set in motion a small turbine. The drawing represents the tube through which the water to be measured flows. The inside is connected with the box in which the turbine (a kind of reaction wheel) is placed. Between the box and the tube is a rubber valve fitted to a metal plate, to cut off the water from the train.

It is easy to see how the apparatus acts. As soon as the water moves in the tube, a current of air is caused, and by withdrawal of the air from the box the tension within becomes less than that of the ex-

ternal air; hence, a motion of the external air inward (shown by the arrows), and the reaction of the air flowing from the turbine, causes a rotatory motion.

The axis of the turbine carries a screw, connected with a train of wheels, by means of which the number of revolutions is shown upon an index-plate. Upon this is cut a spiral line, with several revolutions, along which an index moves, showing the number of revolutions by the distance of its extremity from the middle point. A spring brings the index back to its place.

The train connected with the index-plate is placed in an air-tight cap, provided with an opening for discharging the air necessary to move the turbine. The air is dried and filtered before entering.

Cheating is prevented by means of a peculiar stopcock, or by a rubber ball filled with air, which expands when the air is cut off, and sets another train in motion.

The apparatus is intended to serve as a gasometer, or as a tachometer for the determination of the velocity of streams. It has been tested, and proved accurate, in experiments under heads varying from 2 in. to 150 ft.

THE SPECIFIC HEAT OF AIR.

By F. R. VON SCWIND.

Translated from "The Polytechnisches Journa'."

In the latest works on physics, two values for the specific heat of air are given; one, $c = 0.1686$ for constant volume; the other, $c' = 0.2377$ for constant pressure.

These values were found empirically before the operation of heat as a living force, according to mechanical laws, was determined. If these are applied, c' is found not to apply to the single case of extension, as the following shows.

A heat-unit is a quantity of heat which raises a kilogramme or cubic decimeter of water one degree Celsius.

In a constant volume of atmospheric air of zero temperature, at 760 millimeter, by barometer, the same quantity of heat will produce a temperature $t = \frac{1}{s.c}$; s being the specific gravity of air (0.0012932), and c the specific heat for constant volume; the air consequently not being capable of expansion.

If expansion takes place with unchanged temperature, the change of volume $v = a\ t = \frac{a}{s.c}$; a being the coefficient of expansion for one degree (0.003655).

At the above-mentioned barometer-height this expansion takes place under a pressure $p = 103.34$ kilog. to the square decimeter, and the work required is $A = v\,p = \frac{a\,p}{s\,c}$ meter kilograms.

The quantity of heat (w) required, if k is the mechanical equivalent (424 met.-kil.) for a unit of heat is

$$w = \frac{A}{k} = \frac{a\,p}{s\,c\,k} = 0.41$$

of a heat unit.

Hence, if with $c = 1$ heat unit, the temperature of the air is raised without expansion t degrees, requiring $c' - c$ heat units $= 0.41$, the total required is 1.41 heat units; multiplying these values by 0.1686, we get $c = 0.1686$ and $c' = 0.2377$, as above.

This result shows that the three values c, c', and k, though found by entirely different methods, agree very exactly; and it appears that c' comes directly from c and k, and that it is correct only for a barometer height of 760 millimeters, and therefore has no constant determinable value.

Knowing the heat unit $c = 0.1686$, we have sufficient data to determine a required amount of heat under all possible conditions of expansion and pressure; and any other method seems useless and uncertain.

The equation $k = \frac{A}{c' - c}$ giving $W = c' - c = \frac{A}{k}$ is taken from "Schmid's Mechanick der Gase."

The mechanical equivalent of heat would be proven in an entirely different way; the above is a proof of the correctnes and mutual dependence of the three values of c, c' and k.

The determination of k has made the values of c' unnecessary; and it would be eliminated if the heat-unit for every barometer height were known.

CONSIDERATIONS AFFECTING THE VALUE OF DISTANCE SAVED IN THE LOCATION OF RAILROADS.

By H. HAUPT, C. E.

In the location of a railroad and in the choice of plans of construction, an engineer is not always at liberty to adopt a high standard in gradients, curves, and permanency of structures. He is often controlled by financial considerations and forced to resort to temporary expedients to bring the cost of the work within practicable limits.

In the comparison of lines, distance is a very important consideration, and the value of distance saved upon the shorter line is essential in determining questions of location.

This value is not the same upon all roads and is not constant even upon the same road, but increases with the development of the traffic. The first step, therefore, in the determination of this value as an element of location, must be an estimate of prospective business.

As a guide in the solution of such questions, an illustration will be given from data furnished by a recent report of the Pennsylvania Railroad Company:

Items of Freight Expenses increased proportionately by increased Tonnage, from Report of Pennsylvania Railroad Co. for 1869.

Brakemen	$493,538
Car cleaning and inspecting	67,472
Cars (repairs freight)	961,286
Coal	505,450
Conductors	184,210
Cotton waste	17,057
Engineers and firemen	448,909
Frogs	28,011
Iron rails	576,095
Labor at stations	152,883
Laborers (motive power)	170,824
Locomotive repairs	991,561
Oil, tallow, sponge, wool, etc.	51,209
Tallow motive power	27,898
Teaming	109,125
Tools and machinery repairs	112,010
Wood and labor	81,957
Total freight expenses which are increased by tonnage	$4,979,495
Total freight expenses, permanent and variable	9,035,031
Percentage of variable items	55
Mileage of freight trains	6,904,888
Tons moved 1 mile	752,711,312
Whole cost of moving freight per ton per mile	$1\frac{3}{10}$ cents.
Cost of variable items per ton per mile	.66 "
Cost of mils per ton per mile	$\frac{4}{5}$ of 1 mill.

On the Philadelphia and Erie Railroad the renewal of rails amounts to $\frac{1}{3}$ of a mill per ton per mile, but this item is extremely variable on the same road.

The expenses which are increased by extending the length of a road including those enumerated in former list	$4,970,495

And also,

Ballast	89,732
Cars (road and hand)	22,450
Chains	98,344
Cross ties	198,510
Laborers' tools	206,925
Road bed materials	102,974
Snow and ice (removing)	15,222
Spikes	21,868
Superintendents	26,403
Switches	19,551
Telegraph	18,837
Repairs of tools	37,822
Labor (repairing track)	453,815
Watchmen	98,710
Total freight expenses increased by mileage	$3,381,658
Cost of running freight trains per mile of increased distance, about	$1.00 each day.

The whole freight expenses on the Pennsylvania Railroad, including General Office station and permanent expenses, amounted to 1.30 cents per train per mile.

To ascertain how large an expenditure would be admissible to reduce distance on the Pennsylvania Railroad, allowing capital to be worth 6 per cent., the number of trains passing a given point must be determined.

As the tonnage eastward exceeded the tonnage westward in proportion of nearly 4 to 1, only the eastern trains should be extended, and then an equal number added for return trains. The distribution can be best determined by means of the table of loaded cars passing any given point.

At Altoona 153,202 loaded cars passed eastward; the same number, of course, returned partly loaded or empty. Allowing 16 full cars to a train, the number of trains both ways would be 19,200; add 4,800 passenger trains, and say 2,000 road, ballast, and material trains, the total number would be 26,000, costing $26,000, which, at 6 per cent., is the interest on $433,000, the capital which represents the

equivalent at this time of one mile of distance on the Pennsylvania.

When the Pennsylvania Railroad was constructed a mile of distance saved was considered worth $53,000 or $10 per foot; but the most vivid imagination never anticipated the expansion which the volume of business on that road has attained. Had the engineer been required to estimate the value of distance on the basis of present tonnage, and construct the road accordingly, it would probably not have been constructed at all, as the capital could not have been provided.

In view of these facts, the proper course obviously is to locate an important line on which a heavy traffic will be developed, with reference to the future, and then by temporary lines and trestle road reduce the first cost of construction to suit the finances of the corporation engaged in construction. This is a wise policy, for the reason that, if the road does not prove a success, no improvement on temporary lines will be required; and if a success, then capital for improvement can be procured without difficulty and without paying interest on bonds or dividends on stock; but if a cheap and temporary line is first located as a basis of operations, it cannot be corrected subsequently without an entire relocation and construction.

It appears from an examination of the figures presented, that while the average freight tonnage of the Pennsylvania Railroad in 1869 has cost 1¼ cents or 12 mills per ton per mile, an increased tonnage could be carried at a cost of 55 per cent. or $6\frac{6}{10}$ mills. These proportions result from the large volume of business. On roads carrying less than 500,000 tons the cost per ton per mile is from 2 to 3 cents, and the percentage of cost of an increased business only from 30 to 40, a consequence of the fact that on roads doing a small business, the general and stationary expenses bear a larger proportion to those which are variable.

SUSPENSION BRIDGES*.

In the present day of long-span bridges, more particularly those of suspension, across the wide rivers of this continent, it may not be uninteresting to the civil engineer to trace the successive improvements in their mode of construction, and to fix definitely the claims of inventors and designers to such improvements as they may be respectively entitled to. I am not aware that the subject has been treated in this light before, and therefore, in view of its importance, make no further apology for occupying your attention.

I found in an old book the following sentence:

"The invention of the suspension bridges by Sir Samuel Brown, sprung from the sight of a spider's web hanging across the path of the inventor, observed on a morning's walk, when his mind was occupied with the idea of bridging the Tweed."

The artificer of the web who really guided Sir Samuel Brown, was the American engineer, James Finley, of Fayette county, in the State of Pennsylvania. He, in the year 1796, built the *first regular* suspension bridge across Jacob creek, on the turnpike from Uniontown to Greensburg, in the State of Pennsylvania. He obtained the first patent on this object from the Government of the United States, and the book, "Treatise on Bridge Architecture, by Thomas Pope," published in New York in the year 1811, spread this ingenious invention over the whole world. Some English and French authors, and even Pope, tried to diminish Finley's merits by attributing this invention to the Chinese and Indians, but these people used only ropes or common chains, fastened to trees, and the path was directly on the catenary, without suspended floor.*

The development of the art of bridge

* A paper read before the American Society of Civil Engineers, by CHARLES BENDER, C. E.

* At the discovery of America similar constructions were found there.

Humboldt found in the year 1802 a suspension-bridge across the river Chambo, in Peru, the ropes being 3 ft. thick, made of roots of the Agave Americana. The span was 40 ft.

In the year 1515 the Landsknechte, a kind of regular troops (Germans and Switzers), built a rope bridge across Padus river, in Italy, which they passed with artillery.

In the year 1595 Admiral Coligny, in France, made a rope-bridge near Poitier.

In the year 1734 the army of the Palatinate of Saxony, in Germany, built a chain-bridge across the Oder river, near Glorywitz, in Prussia.

The bridge across the Tees, in England (1741), 70 ft. long and 2 ft. wide, was like those constructions in China and Thibet, having chains fastened to timbers, the planks laid on them directly.

building is showing and proving how deeply James Finley had studied his task, and how much we owe to him.

The principal features of his invention consisted in the application of artificial stone abutments, in the introduction only of two chains, one at each side of the bridge, the links of which were as long as the distances between the cross-bearers or joists. Finley applied ¼ of the spans for the deflections of cables, introduced suspension rods and stirrups to support the joists, and arranged the anchor chains at the same angles as the main chains, to avert powers acting to throw down the piers.

The most interesting of the novelties, and one upon which Finley apparently laid a great value, was the arrangement for distributing the load over a great extent of the bridge, thereby aiding to divide it over many suspenders, and to stiffen the otherwise movable floor against change of shape.

His specification reads as follows:

"To bind and connect the whole that they have the same effect as a *platform of one piece*, 4 or more joists will be necessary for the upper tier—to extend from end to end of the bridge; each will consist of more than one piece, the pieces had best *pass each other side by side*, so that the *ends may rest on different joists* on the lower tier. The splice will then extend from one joist to another of the lower tier, and must be bolted together by one bolt at each end of the splice. The planking floor is laid on the upper tier."

Herewith the inventor formed strong beams, continuous from one end of the bridge to the other, and the continuity itself gives the utmost certainty, that these beams, which were no directly bearing parts, had the aforesaid important object, to stiffen the floor, prevent greater changes of form, or, in other words, to neutralize the momentum arising from loads and wind.

The method employed was sufficient for the spans at that time in use, and, in connection with the stiff railing, fulfilled entirely the conditions necessary for a good bridge for common traffic. For the time in which Finley lived, his bridges were astonishing structures in reference to the insufficient knowledge of the art of frame bridge building, and spans of 306 ft. at the commencement of the 19th century appear bolder than 1,200 ft. in our days. We can learn by studying Finley's plan how the neglect of his well-founded directions caused many disasters to suspension bridges.

It is astonishing how few understood him. Instead of keeping the stiffening continuous beams, and instead of proportioning the same according to the spans and loads of the bridges, it was believed to be an unnecessary weight and increase of cost of bridges; and instead of adapting great deflections of cables or chains, it was believed to be a better arrangement by taking flat arcs, and deflections equal to $\frac{1}{7}$ of the spans, whereby the cost of bridges became nearly double as great as before.

Till the year 1801, according to Finley's patent, 8 bridges had been built in the United States, and there have been added 40 others between the years 1801 and 1808. The largest of all was the Schuylkill chain bridge, of 306 ft. span.

It is not uninteresting to know the names of some of the first buildings of this kind.

The Potomac Bridge, near Washington, had 130 ft. span, its floor being 15 ft. wide; the Cumberland Bridge, in Maryland, had the same span; the Brandywine Bridge, near Wilmington, was built with 145 ft. span, and a 30 ft. wide floor, and 2 other bridges were built of 120 ft. span each, at Brownsville, in Fayette county, in the State of Pennsylvania. A bridge across the Merrimac, 3 miles from Newburyport, in the State of Massachusetts, carried out by an engineer of the name John Templeman, of the District of Columbia, is more particularly described, and is one of the most interesting buildings in the history of bridges. The span of this bridge was 244 ft.; the abutments, 47 ft. long and 37 ft. high, were made of good masonry. The 2 roadways, of 15 ft. width each, were strong enough to allow for the passage of horses and carriages, whatever their speed. Ten chains, each 576 ft. long, were made to bear 500 tons with perfect security. Three of the chains were fastened on each side of the bridge, and 4 in the middle. "The railing was stout and strong," a construction, which "contributed much to the stiffness of the floor." Thomas Pope himself calls it a wonderful structure, describes the railing as contributing much to the stiffness of

the floor, and states that Templeman's talents and improvements had earned for him a great reputation as engineer of such work. He also reported that the motion of the floor of the Merrimac bridge was "*very little perceptible*, whatever the *speed of any kind of traffic*."

The bridge across the Lehigh, built in the year 1815, near Northampton, in Pennsylvania, consisting of two whole and two half spans, 475 ft. long, bearing two tracks for carriages and two 6 ft. wide footpaths, was the *first mentioned* suspension bridge of more than one span.

The *application of wire for suspension bridges* is also an American invention, for the first wire-bridge was built *before* the year 1808, at Philadelphia, across the Schuylkill river, with a span of 408 ft. I found in the book on wire-bridges, by the French engineer, Seguin, published in the year 1824, that a report on the American canals, written by Mr. Galatin in the year 1808, and copied in a French book from the year 1820, mentioned the wire-bridge at Philadelphia. The same bridge is also described in the "Bulletin de la Société d'Encouragement," in the year 1816.

According to these notices, the existence of the American wire suspension bridge was well known in Europe a long time before the first regular suspension bridge was built there.

Pope's book was well known in France, and Seguin, as well as the famous French engineer, Navier, made use of it. Finley's important invention, in connection with Templeman's improvements, as well as Pope's book, and the wire-bridges built in this country, were known in England by Samuel Brown and others in the year 1814, and it is most probable were known in France, for the brothers Seguin, French engineers, seem to have been in England, and Navier especially was sent there to study suspension bridges.

At that time a Frenchman of the name of Poyet proposed a kind of stay-bridges, consisting of high wooden masts as towers, from the tops of which were starting many stays to both sides, supporting the floor.

But the English engineers were the first who proposed and applied stays for suspension bridges, in connection with cables, as well as without them.

The first of these bridges was built by Richard Lees, at Galashiel, across the river Gala, in the year 1816, of a span 112 ft.; it was like the 2 following, a wire-bridge. The bridge at Kings-Meadow, across the Tweed [span 110 ft.], was built in the year 1817, and another structure, at Thirlstone Castle, 125 ft. long—both with stays. At Kelso, on the Tweed, a bridge of 300 ft. span was built for carriages—the roadway 18 ft. in width. A bridge at Dryburgh Abbey, with stays, was 260 ft. long, and very movable; so much so, that 4 persons could shake it so as to break one of the stays. In the year 1818 a wind destroyed the whole structure. Rebuilt according to Finley's system, provided with strong longitudinal beams, strong railings and anchors, like those at Niagara bridge, resisted the obnoxious motion. Especially is it stated that the *railing resisted all upward movements*. The use of anchor-chains, to prevent side and upward movements of the floor, is, therefore, already very old, and Sir Samuel Brown often made use of them.

The bridge at Dryburgh is interesting in another reference, as it is the first wherein the chains were convergent in middle of the span. At the towers of this bridge the distance apart of the cables was 12 ft., and in the middle of the bridge it was only 4 ft.; the object being to reduce the side motion. But the engineer, Stephenson, already observed that he preferred to keep the parallelism of chains, and rightly, as I hope fully to convince you in a future communication.

A great many of the stay-bridges broke down, and after many sad experiences, the use of stays has been entirely rejected by English engineers, notwithstanding they have been reintroduced into this country.

Navier saw different bridges built by Brown in England, and he describes the action of the stays in aiding to support the floor; others were introduced horizontally, but inclined to the longitudinal axis of the bridge, to reduce the side motion, and he criticised sharply the combination of stays with suspension rods and chains or cables.

The use of separate tension cables attached to the 2 towers, working horizontally or verticallyagainst the action of the wind; the application of pendulums to support the cables on the pillars, allowing expansion and contraction of cables, are

ideas of the famous engineer Brunel. These applications are made at Brunel's bridge on the Island of Bourbon, and are copied at the suspension bridge across the river Meuse, at Liege, in Belgium, and at the Alleghany bridge near Pittsburg.

Telford, the engineer of the Menai Straits suspension bridge in England, as far as I can learn, added the improvement of saddles on rollers, supporting the cables or chains, to allow for the movements in case of change of temperature. The railing of this bridge was proposed 6 ft. high, the span being 560 ft.

I have mentioned that by the French Government, in the year 1821, Navier was sent to England to study the existing suspension bridges, and to report on the same. He collected the different historical notices, described Finley's and the English bridges, and gave the theory of movable suspension bridges in his classical book, published in the year 1823. The curve of the suspension cables when loaded, Navier first regarded as parabola, rejecting the complicated older formulæ as given by Jacob and John Bernouilli, Huyghens, Euler, and others. It is to be regretted that this celebrated and highly scientific man overlooked the influence of wind acting from below on the floor, and thus becoming the most dangerous element to destroy suspension bridges. Indeed, Navier's theory and his reputation contributed much to the false judgments about Finley's improvements, and caused the error of introducing *small deflections* and of omitting the *American longitudinal beams and railings*, these important stiffening elements, which, in the right proportions, are inseparable from any good suspension bridge.

Finley expressly advocated the construction of *platforms of one piece*, but Navier and his followers supposed a *perfectly movable floor*. Finley applied $\frac{1}{4}$, Navier $\frac{1}{12}$ to $\frac{1}{15}$ of the spans for deflections. Finley prevented the undulations by his stiff platform; Navier believed he could prevent greater deplacements by flat catenaries. This is the great antithesis of these two celebrated engineers, and every scientific bridge builder must concede that Finley stood much nearer to the perfect solution of this problem than Navier.

But notwithstanding, Navier's book was of great value to science, and he opened for investigation many interesting questions.

Navier paid attention to the effect of change of temperature on suspension bridges, and after having examined the use of rollers on the towers, he gives some hints about the effect of the same forces on the platforms, which he supposes to be movable. His own words in this respect are:

"By applying continuous longitudinal pieces in the platform of the bridge, it will be necessary to compound these pieces of parts connected by *joints*, which *leave a little freedom*, so that the adjoining parts *can slip* on the others, where the *heat* is lengthening the same."

But it is not to be understood that Navier meant to apply such slip-joints to the chords of a truss, for in our climate such a truss would not begin to work before it was bent to deflections equal to about $\frac{1}{60}$ of the span. Hence, it follows that if such a truss with slip-joints were applied to a suspension bridge, it would not work at all, but merely act as a dead weight.

In the same classical book, Navier describes the suspension canal-bridge, built by Count Chabrol in the department of Puy-de-Dôme, in France, the length of which was 650 ft., and he gives calculations and plans of a project of this kind. These ideas and plans have been applied by constructing the Pennsylvania canal-bridge for spans of 160 ft.

The first suspension bridge on the continent of Europe was built in the year 1823 at Geneva, in Switzerland, by Colonel Dufour. If was a wire bridge.

In the year 1824 the elder Seguin published the first edition of his work on wire bridges; a book important in many respects, giving many new ideas and improvements.

There the utility of the stiffness of the platform of suspension bridges was not overlooked, as was done by Navier and the English engineers. On the contrary, the meaning and the importance of stiff railings as well as of longitudinal beams was fully appreciated.

I must not omit to translate a portion of this work, throwing light on the fact, that James Finley and Templeman are to be regarded as inventors and improvers of suspension bridges with stiffened floors,

rejecting all later pretensions and claims of this kind.

In the aforesaid book is to be found :

"One of the greatest inconveniences of suspension bridges are the vacillations arising from moving loads of any considerable masses. To prevent these, there should be employed all possible means affording rigidity ; the very best of all existing of which I know is the arrangement of *strong trusses as parapets of the bridges.* These have to consist of *long pieces of wood* forming the *frames*, and of wooden *Andrew crosses* put together at *right angles.* The connections of the different pieces should be made by *iron bolts*, piercing the *frames or chords between the joints of the diagonals*, allowing any desired tension and great rigidity."

Further Seguin says :

"The first quality of the floors or platforms of suspension bridges is to have as much rigidity as possible, and to obtain it care is to be taken to fasten together the different parts, so as to get a continuity preventing any separation. It is customary to attach the suspension rods *to* cross bearers which are supporting the floor itself, but it is possible as well to apply longitudinal pieces to support the cross-bearers, and it seems to me to be far preferable to establish in all cases longitudinal flooring before cross-bearers. The longitudinal pieces had to be of the greatest possible dimensions, their joints to be well connected to avert those horizontal movements, which are consequences of the deficiency of continuity in the floor.

"*The Americans had adopted ¼ of the spans for deflections of cables. This disposition, being very favorable in reference to solidity, is inconvenient in regard to deplacements, which become always the less the more the deflection of cables is diminished. But the Americans have neutralized that inconvenience by adding to the floors great masses, and using strong railings, to increase the rigidity.*

Concerning the said masses, Seguin meant evidently Finley's longitudinal and continuous beams, laid on the cross-bearers; the weight and action of which reduced the side motions caused by wind, and which had, besides this effect, the more direct object which Seguin mentioned before, but did not understand fully. Navier's influence on Seguin is evident already.

The brothers Seguin introduced the method of boiling the wire in oil, thus giving a good coating as a preventive of rust. But they observed that the wire, after the process of boiling, lost a portion of its strength, an observation which is confirmed by newer and very minute experiences of reliable men.* Indeed, the temperature of boiling linseed oil is at 600 deg. Fahr., which is the same temperature required to soften steel, at which that dark-blue color, so characteristic of the tempering of steel, is observable.

The method of covering the chains with white instead of any other color, as was Finley's practice, is first mentioned in the description of the Hammersmith bridge in England. The same Hammersmith bridge, as seen in the year 1854, was stiffened horizontally by cast-iron beams, suitable chords and diagonals, and the vertical movements were prevented by strong railings. This was perfectly sufficient for common traffic, and the Hammersmith bridge was celebrated for its good proportions and strength.

Many bridges of this time suffered by gales of wind; many of Brown's structures, and generally those near the sea, and more especially those constructed with stays, were destroyed entirely; others badly damaged. Telford's Menai bridge, for instance, was extensively injured, and the engineers fell into the great mistake of preventing the undulations and motions, caused by wind, by increasing the dead weight of the bridge itself. The floor of the Menai bridge has a weight of 97 lbs. per superficial square foot. But the evils of this system soon produce a change in the opinions of the engineers, and it was the engineer Rendel, to whom was confided the repair of the suspension bridge at Montrose, who was induced to apply a good method of stiffening the floor of suspension bridges. Though undoubtedly Finley and Templeman are to be regarded as the first constructors of stiffened suspension bridges, as we well know, and as Rendel's method is merely one of its applications, yet the ideas in that time were disturbed to such a degree, that he is to be regarded as the true reformator of suspension bridges, and as the man who again brought to clear understanding the idea of longitudinal beams

* Experiments by Professor Karmarsch and Engineer Brix, in Prussia.

and trusses reaching from one end of the bridge to the other. Rendel also condemned more decidedly the use of stays, and proved by fact the truth of his judgment.

This bridge of Montrose was built in the year 1825, by Samuel Brown, its span being 432 ft., deflection of cables equal to 42 ft., and width of floor 26 ft. In the year 1838 the platform was destroyed by a heavy gale, and in the year 1840 the chains gave way with a load of 700 men on the floor, whereby a considerable loss of life was caused.

Rendel, in his report, says :

"In the anxiety to obtain a light roadway, mathematicians, and even practical engineers, had overlooked the fact that when lightness induced flexibility and consequently motion, the force of momentum was brought into action, and its amount defied calculation.

"The author has long been convinced of the importance of giving to the *roadway of suspension bridges the greatest possible amount of stiffness in such a manner as to distribute the load or the effect of any violent action over a considerable extent.* The platforms of large bridges in exposed situations are acted upon in so many different ways by the wind, that he had *an objection to the use of stays or braces to counteract movements which ought rather to be resisted by the form of the truss-structure.* Holding such opinions, he determined to adapt a *framing, which, although connected rigidly in every direction, should nevertheless be simple, composed of two parts, capable of being easily renewed, should distribute its weight uniformly over the chains, not be subject to change from variation of temperature, and not augment the usual weight of suspended platforms.*"

According to these principles, which are embraced entirely in the old American inventions, but more defining the same, Rendel repaired the Montrose bridge in the following way : "Instead of cast-iron cross-bearers, he adopted wooden joists 13 ft. by 3½ ft., bolted together and trussed with a round bar of 1⅛ in. diameter; every 6th beam had a deep trussed frame on the under side, so as to give great stiffness above and beneath the cross-beams ; on each side of the carriageway were bolted 2 sets of longitudinal timbers, 4 in each set ; they were further united by cast-iron boxes at intervals of 10 ft. A curb of timber, 11 in. by 6 in., was attached to the ends of the cross-bearers, and extended the whole length of the platform. To add to the stiffness afforded by this construction, the author caused to be passed through the spaces between the pair of longitudinal beams, a series of diagonal truss-pieces of timber, 6 in. sq., with the ends stepped in the cast-iron boxes, which at every 10 ft. grasp the beams. On the other end of these diagonal truss-pieces, an iron screw bolt, 1¼ in. diameter at every 10 ft., and a contrivance of wedges in the cast-iron boxes, enabled any degree of tension to be given to the framing. The roadway was thus stiffened by 2 of the strongest kinds of framing in parallel lines, dividing the carriageway from the footpaths."

This truss-work, with the perfect understanding of the working momenta, was expressly made to resist flexures upward as well as downward, an arrangement omitted in one of the greatest existing constructions.

The requisite horizontal stiffness was obtained in the following way : The carriageway was formed of 4 thicknesses of Memel planks, the 2 lower layers, each 2 in. thick, were placed diagonally with the transverse beams crossing each other so as to form a reticulated floor, abutted against the longitudinal beams. They were firmly spiked to the beams and to each other at all the intersections, and upon them was laid and spiked a longitudinal layer of planking 2 in. thick. Each layer was closely jointed and caulked, and the upper one was laid in a mixture of pitch and tar ; a composition of fine gravel and sand, cemented with boiled gas-tar, was laid over the whole, to the thickness of 1 in., forming the road track."

The absence of Brunel's counter-chains and of Brown's counter-stays, and other unnecessary and even dangerous furniture, is to be regarded as highly commendable.

"The whole formed a compact mass of braced wood-work, the diagonal planking giving the horizontal stiffness, and the two trussed frames insuring the vertical rigidity."

It is interesting to know the weights of this structure, as important concerning the art of building suspension bridges with stiffened floors.

The weight of the roadwork was	131	tons.	Per running ft. 0.53 tons,
" of cast and wrought iron	37	"	
" of suspension rods	21	"	
" of fencing (wrought iron)	9	"	
" gravel concrete	30	"	
Total	228	tons.	

or 47½ lbs. per superficial sq. ft., for the entire roadway. Subtracting the gravel concrete, it is 41 lbs. Before the bridge was stiffened, the weight was 44 lbs. per sq. ft.

The bridge has borne, without injury, heavy gales, as could be foreseen, and the stiffness has given confidence in the strength to all who have examined it.

The English engineers agreed with Rendel, and the engineer Vignoles eulogized this excellent communication for the practical conclusions which it contained. "He found it not difficult to foresee, that by carrying out the system of *adopting well-trussed framings* to the platforms of suspension bridges, *sufficient rigidity* would have been obtained for *locomotive engines and carriages on railways* to traverse rivers or ravines by means of these bridges, instead of the costly viaducts or heavy embankments; and Mr. Rendel saw no difficulty in giving any required amount of rigidity to the platforms; it was only necessary to increase the strength of the framing, to enable the roadway to bear with perfect safety the passage of an engine and a train of carriages.

In the mean time the wire bridges found a favorable reception in France, which is full of admirable structures of this kind, and the French engineers brought the manner of constructing cables to the high degree of perfection of our day.

After the preceding introduction of wire bridges in England and Switzerland, the brothers Seguin constructed the first wire suspension bridge in France, in the year 1824. All the existing methods of splicing wire, of bringing up the cables, have been studied, and theories of great mechanical value have been invented.

The cables were first made on land and then carried on the towers by machinery, but soon the French engineers began to build them on the towers themselves. Very perfect methods have been employed, securing all possible equality of tension in the single wires; and as greater perfection always requires more time and trouble, these methods are more expensive than those of a later origin, which, shortening a little the time of construction, are not securing the same equality throughout.

Now, the time to make a wire cable of 1,600 ft. length, is about *one year*, which involves *a great loss when we consider that steel chains can be obtained cheaper, much more secure, much lighter and better*, than any wire rope can be, and by the use of which *the time for building* suspension bridges is *considerably reduced*.

Such a steel chain bridge was built in Vienna in the year 1829, by the Austrian engineer Mitis. It is praised in all reports as a strong structure.

The wrappings of the French cables are made at intervals of about 1 ft.; in later times the wrappings have been made continuous.

In the year 1831 the French engineer Vicat, in his report on the suspension bridges across the river Rhone, described his method for building wire bridges in place, directly on the towers and abutments, a method which, essentially in the same manner, was copied by erecting the Niagara and Cincinnati bridges. This method is described as follows:

"The towers and abutments of a suspension bridge being finished, the points of attachment ready to receive the cables, and supposed that a number of double wires of equal lengths, forming circuits, are wound on different reels, these *wires are drawn from one pillar to the other by means of a thin endless rope*, like the guide-rope of a flying ferry, and moved like the *chain of a chain-pump*."

By this method Mr. Vicat proposed to make and suspend cables, with less cost, with fewer workmen, and in shorter time than before. He said it was not difficult to reduce *the number of cables to two*, if it was desired; whereby the surface exposed to oxidation would be diminished; the tension of the single wires would be uniform, whatever the thickness of the cables; the apparatus for elevating the cables be simplified, and the greatest possible spans would be admissible.

More details on this subject can be found in the article on bridges across the river Rhone in the French "Annales des Ponts et Chaussées," 1831, volume first.

Mr. Chaley, the engineer of the celebrated suspension bridges at Friburgh, in Switzerland, worked out Mr. Vicat's method, and often had occasion to apply it. He, according to the same method, built the second suspension bridge at Friburgh, in Switzerland; further, the bridge "de la Charité," across the river Laire, a suspension bridge in Paris, another at Percy, in the Jura mountains, and the bridges at Cormery, across the Indre, and of Beaumont, across the Sarthe, in France.

Vicat's method was further employed at a bridge at Tours, in France, for transporting materials. Interesting details are found in the "Annales des Ponts et Chaussées," year 1841.

Other methods for constructing the cables of suspension bridges directly on the towers and abutments, is that of the French engineer Le Blanc, constructor of the splendid bridge at Roche-Bernard; and, after him, that method introduced by the French engineer Le Clerc, the constructor of the suspension bridge at Lorient, across the Scorff. The anchorage of these bridges (the first is of 643 ft. span, the other 610 ft.) is interesting, as the cables form one continuous belt, laid around the abutments in suitable vaults, allowing free circulation of the air, as well as to repair the painting of the wire from time to time. The two cables, at both sides of these bridges, have the *same deflections*, an arrangement which is not objectionable. (The descriptions can be found in the "Annales des Ponts et Chaussées," 1850.)

The French methods and designs have been used in our country; especially the method of constructing the cables directly on the towers, in the year 1844, at the Alleghany suspension bridge, near Pittsburgh, and Vicat's invention was a little, but not essentially, modified at the construction of the Niagara and Cincinnati suspension bridges by Roebling.

A picturesque suspension bridge is that at Cubzac, across the river Dordogne, in France, with five continuous spans of 363 ft. each, the towers being constructed of iron (iron towers 82 ft. high; total height of towers above low water, 126 ft.).

Iron towers also are used at the chain bridge at Seraing, in Belgium, and at the chain bridge at Muehlheim, on the Ruhr, in Prussia.

Since the accident of the wire bridge at Angers, in France, in the year 1850, many of the wire bridges in Paris have been replaced by truss and arch structures, and a law is introduced directing tests of wire bridges from time to time. During such a test in the year 1861, the suspension bridge at Mirabel sur L'Eggues broke down, the cable having been destroyed by rust in the interior.

The elder Seguin, in the year 1840, had an opportunity to apply the old American method of stiffening suspension bridges, which he appreciated highly, as has been demonstrated. *He was the first man, at least in Europe, who built a suspension bridge for railway purposes, and with full success.*

His work was an auxiliary suspension bridge across the Soane river, built in the year 1840, when some spans of the wooden railway bridge were swept away. The two spans of his bridge were 137.5 ft. each, the deflection of the cables was $16\frac{2}{3}$ ft., girders $8\frac{1}{3}$ ft. high, composed of wooden beams 9 in. by $2\frac{1}{2}$ in., and chords of 13 in. by $6\frac{1}{2}$ in., connected with the longitudinal beams of the floor by screwbolts, and kept in vertical position by braces, were to stiffen the floor vertically. The three cables on each side were connected by numerous ligatures. This new bridge was reported to have been *as stiff as the former truss bridge*, and was used as a railroad bridge during four years, with perfect success, and then the remaining wooden frame bridge as well as the suspension bridge were replaced by a stone structure.

This bridge also had neither stays to support the floor, nor stays to add for horizontal stiffness.

Our vice-president, Mr. Julius W. Adams, kindly showed me a plan of a stiffened railroad suspension bridge across Kentucky river, at Frankfort, which he passed over in the year 1852. It had been built some years previously, but precisely when, or by whom, he was unable to ascertain. It is possible that it was built before Seguin's structure. Besides this, it had also no stays. The spans of this stiffened suspension bridge were 100, 261, and 200 ft., the lattice girder was 6 ft. high, the distances of suspension rods and likewise of the cross-bearers equal to 3 ft., and floor with girders had the calculated weight of 930 lbs. per lineal foot.

In the year 1845, the Austrian engineer,

Schnirch, who built the well-known suspension bridge at Prague, proposed a new system of suspension bridges, the curves consisting of two pairs of parallel chains, one above the other, and both connected by triangular trussings. At these bridges the chains themselves represent a stiff inverted arch, and are to be calculated only as such. A bridge of this kind, before Schnirch had occasion to introduce his system in practice, was carried out in Switzerland, across the river Aar, near Aarau, but the distance of the chains was too small to be considered as sufficient.

Schnirch's plan was carried out for two tracks in Vienna, in the year 1861, to bridge a canal of the Danube river. As Schnirch's plan is of so old origin, and an ingenious invention, and as the suspension railroad bridge in Vienna is until this day the best though not the longest stiffened suspension bridge, I will proceed to describe it.

Two parallel chains on each side, consisting of alternately eight and nine link plates each, are placed at a distance apart of 4.1 ft. The trussing consists of a single triangular system, the diagonals being 6.4 ft. long, the links of the chains are 10 ft. long and 6 by 1.35 in. and 6 by 1.16 in., respectively; two pairs of chains, in a distance of 31 ft. from centre to centre, limit the floor sideways; four longitudinal trusses of wrought-iron, consisting of uprights and crossing diagonals are made to stiffen the floor and to offer suitable points of attachments to the suspension rods, at distances of about 5 ft. The suspension rods themselves are made adjustable. The longitudinal trusses are 2.5 ft. high, and represent likewise the chords for a horizontal trussing, the uprights of which are the cross-bearers, iron girders of 2.5 ft. height, and the diagonals are strong iron bars, fastened by rivets.

The span is 252 ft.; anchorage, architecture of piers, and performance are entirely successful.

Though this bridge has no great span, it is to be regarded as the best and most complete, in point of principle, of all existing suspension bridges. I therefore believe it is an act of justice to give to a man of the originality of Mr. Schnirch the honor which he has a right to claim.

During this time the American engineers, occupied in improving the wooden truss bridges, did not forget to appreciate suspension bridges, and that they constructed the greatest spans, is well known. I mention the former Niagara bridge, of 1,042 ft. span; Ellet's Niagara bridge, of 760 ft.; and the unfortunate Ohio bridge, at Wheeling, of 1,010 ft. span. The latter, without any kind of stiffening, succumbed to a heavy hurricane, in the year 1854. Stays would not have prevented this accident, for, under the same circumstances, stays were rejected at an early day of this century.

At the time when the Britannia tubular bridge was to be built, R. Stephenson proposed a stiff suspension bridge, in form of an iron tube, suspended by chains. Many and costly models were built, as at this time no theories existed either of truss or of suspension bridges. The tubes in these models were made stronger and stronger after every experiment; and, lastly, the chains were no longer necessary and were dispensed with, and the iron tubular bridge was the result.

It is plain that the Niagara railroad bridge is the direct application of Stephenson's plan.

This work, as well as the Cincinnati bridge, are sufficiently known, and therefore I do not consider it to be necessary to describe them, nor to demonstrate that they are to be appreciated as great works of American enterprise and boldness, but exhibit nothing commendable in the way of *invention*.

Before finishing this short sketch of the history of suspension bridges, I have still to mention that the third possible arrangement to stiffen a suspension bridge was carried out in London in the year 1862 by the engineer Barlow, who bridged the Thames by 3 single spans of 280 ft. each. This work is named the Lambeth bridge.

The said system consists of cables, horizontal beams, and uprights, with diagonals between the cables and beams, so that these represent the chords of the truss-work. This arrangement is the most objectionable of the 3 possible manners of stiffening suspension bridges.

The detailed construction as furnished by Barlow is unnecessarily complicated, and the tube, this favorite monster of English engineering, is not forgotten.

Over 3,000 men are employed in the construction of the N. Pacific Railroad.

SOME OF THE METHODS OF SHEATHING IRON SHIPS WITH COPPER AND ZINC.*

By MR. W. FORSYTH BLACK.

From "The Engineer."

The author first referred to the very serious evils of corrosion and coating of the hulls of iron vessels, and the failure hitherto of compositions and paints to obviate these grave disadvantages; and described the results of Admiralty trials in this direction. After showing the loss to shipowners from diminution of speed, and the great cost incurred by them for frequently docking their ships, he proceeded to describe the plan of sheathing iron vessels with copper invented by M. Roux, captain in the French navy, whose process has been applied to several of their armor-plated ships. By this method, while great care is taken in the insulation of the hull of the vessel from its copper envelope, a very ingenious means is adopted for securing the sheathing to the plate of the ship. Holes are bored in rows at about 2 in. apart of a depth of $\frac{1}{3}\frac{1}{2}$ in., and a recess is formed of a greater diameter than the hole by means of a spring rose bit. The rivets are formed with a base, a collar in the middle, and a head, and a hollow set-tool is employed for riveting them. To fasten one of them in its place, the head is inserted in this set tool, which bears on the collar, and the base placed in one of the holes. The head of the set is struck with a hammer, and the base of the rivet, which is of a semicircular hollow section at the bottom, fills up the recess in the hole, and is firmly fixed and the head projects. When all is prepared the copper sheets are laid on and the projected heads of the rivets are riveted down. There is however, always, he considered, danger of the insulation of the copper sheathing failing through some accident, if not from other causes, besides the drawbacks to its use on account of the cost of application and material. The author went on to describe what had been done in the direction of applying some other kind of sheathing which would not be dangerous to iron by being brought into contact with it. He gave an account of the experiments which had been made by the Admiralty and others to test the efficiency of covering iron plates with zinc, and which had been proved very satisfactory, especially where no insulating medium had been interposed between the two metals; this result might have been expected, he showed from the position of zinc to iron in the electric scale of metals; just as iron is certain to be destroyed by contact with copper when salt water can reach both so placed, so is iron preserved by contact with zinc under the same conditions. He then described Mr. Daft's proposed method of building ships with a special view of providing a simple means for the attachment of zinc sheathing. That gentleman proposes to rivet all the plates of the vessel directly to the frames or ribs, and that the joints shall be made on the lap principle throughout, but in such a way that a flush surface shall be obtained. This he effects by leaving a space along the sides and ends of the plates equal to their thickness. After the plates have been caulked against the joint straps from outside, and then against the plates from inside of the vessel, he fills up the spaces with strips of compressed teak, to which he secures the sheathing with iron or zinc nails (by preference the former) of such a length, that on meeting the iron at the back of teak strips the points turn round and are clinched. He concluded by describing plans for applying zinc sheathing to ships built on the ordinary in-and-out strake system, by filling the spaces between the out strakes by teak planks equal to their thickness. By this means a flush side is formed, and the sheathing can readily be nailed on, and the nails clinched as shown above. He also suggested that the raised holes of M. Roux's system, and zinc rivets, might be employed for zinc sheathing, instead of the methods indicated.

* Abstract from a paper read before the Civil and Mechanical Engineers Society, London.

The annual account of coal mined and shipped in Nova Scotia has just been issued by the Chief Commissioner of Mines. In 1827, 11,491 tons were shipped, and in 1869, 578,062. The total production in the 43 years was 9,023,701 tons.

GUNPOWDER.

From "The Mechanics' Magazine."

A late number of the "Westminster Review" contains an elaborate and ably written article on gunpowder, from which we cull the following facts for the information of our readers.

Improvements in the manufacture of gunpowder have not kept pace with the advance made in the manufacture of guns. Indeed, all military manufactures have been improved within the last few years to an unexampled extent, whilst the production of gunpowder, so far, at least, as the proportions of its ingredients are concerned, remains almost exactly as it was many years since. Some progress has, however, been made in the methods of preparing and purifying the ingredients, whereby the deadly composition is rendered more suitable for the particular purpose for which it is employed. As in the manufacture of guns and iron-clad ships so it is with gunpowder—scientific knowledge must be brought to the aid of practical experience. Hitherto the knowledge of the chemist has not been brought sufficiently to the aid of the gunpowder manufacturer, and hence the improvements made by the latter have not been on a level with those of the artillerist or the manufacturer of small arms. It is owing to this comparative paucity of scientific knowledge that such small strides have been made in the improvement of the fiery compound. It appears that the cause of this slow advance rests, mainly, with the manufacturers. There is plenty of chemical knowledge to be obtained in this and other countries; but that is of little avail without the conviction of the necessity for its utilization on the part of the manufacturers of gunpowder. The absence of this conviction on their part has been injurious in many ways. It has not only indirectly increased the expense and delay in the improvement of guns, but has been the cause of many explosions, resulting in great loss of life and destruction of property. But these times are passing away, and gunpowder manufacturers are beginning to recognize the necessity of bringing chemistry to their aid.

It has until recently been the chief aim of the manufacturer to produce a strong powder, but it was essential that the powder should be clean—or, in other words, should leave but little residuum to foul the gun. In attaining cleanliness a strong powder was obtained, and as guns were enlarged in calibre the charges of powder were increased, till at last the problem became, How to make a gun strong enough to resist the charge of the required strength of powder? But this is not the case now; powder is now made to suit the guns for which it is intended instead of making guns to stand the force of the powder. Two great objects have thus been gained—a diminished pressure on the gun and an increased initial or muzzle velocity.

We shall entirely pass over the elaborate description of the manufacture of powder generally and the various alterations and improvements it has undergone during the past few years, given in the "Westminster Review;" and we must also leave unnoticed the legislation which has taken place with the view to regulate the making, keeping, and carriage of gunpowder and other compositions of an explosive nature. We may here just stay to record that the writer in the "Westminster Review," when speaking of the liability of "press-houses" to explosions—and particularly of the press-house explosion at Waltham Abbey—says: "We believe it is an ascertained fact that copper and copper can be made to produce a spark, but gunpowder makers are slow to believe it." Now with reference to this observation we may state that so long ago as 1859, when writing in the pages of this journal of the explosion at the Hunslow Gunpowder Mills, we said,* "with gunpowder copper as a metal has, from the time of Roger Bacon been supposed to be friendly, and men have not doubted that the former would patiently submit to be knocked about by the latter with the greatest unconcern; yet after such a fact has been almost universally accepted as beyond dispute, experiments in France and Austria incontestably prove that, under special circumstances, copper is as liable to produce its ignition as iron.

* Vide "Mechanics' Magazine," April 8, 1859, p. 230.

Indeed, at the accident at Hatton, about a year ago, a spark was seen to escape from the copper tool used by one of the men. And now we have iron rollers substituted at the Hounslow Powder Mills in lieu of stone, as iron is considered to insure an additional safety from accidents." We are of opinion that if gunpowder manufacturers have not yet settled this point beyond all grounds of dispute, it is time they had; their not having done so would go far to prove the justice of our foregoing observations.

It is, however, more particularly to the manufacture of "pellet" and "pebble" gunpowder that we wish to refer. Mr. Cardwell, in his speech to his constituents at Oxford on the 2d inst., said that powder was not like wine, that it would not improve by keeping, and that we had enough in store for the average consumption of several years to come. "But," said he "there are changes taking place in ammunition and guns which materially affect the question of powder, and this applies especially to the kind of powder recently introduced for heavy guns. These improvements have been made in powder for heavy guns during the time I have held office. Only in May last a particular kind called 'pebble' powder was approved, and we immediately set to work to adapt our machinery for the use of pebble powder, and are most desirous of getting all the best pebble powder we can get at a fair price as rapidly as possible." We hope that Mr. Cardwell's good intentions will be carried out.

When charges of 50 lbs. of powder were required, it was found that the severe strain caused by the combustion of "large-grain rifle" (L.G.R.) was very injurious to the guns. It was comparatively detonating in its action, and it has been asserted that "no other guns in the world have ventured to employ it." It therefore became a vital question whether a powder could not be made which, while as powerful or more so in the direction of the shot, should exercise a less destructive pressure upon the gun. A powder having its grains of a uniform size and shape, of a uniform density and slow in its action, would, it was thought, meet all the requirements, and "pellet" powder was first provisionally adopted. The "pellets" are procured in the following manner:—The broken millcake is placed in cylindrical holes, into which closely fitting punches are forced by hydraulic pressure, so adjusted that the required density can be obtained. The powder is then glazed, if thought necessary, and dried in the usual manner. The particulars as to the size, etc., of these "pellets" are as follows:—

Range of density of the pellet	1.65 to 1.7.
Diameter of pellet	0.75 in.
Depth	0.485 in. to 0.495 in.
Diameter of cavity, or indentation in end of pellet	0.2 in at top. 0.15 in. at bottom.
Depth of cavity or indentation in end of pellet	0.25 in.
Range in weight of the pellets	85 gr. to 95 gr., *i.e.* about 75 to the pound.

The pellet may, of course, be made of different forms. A cylinder with both ends flat is as easy to make as one which has one end flat and the other indented. Lately, another kind of pellet has been adopted; this is a cylinder with both ends convex. A large quantity of this powder has been manufactured in England for continental use.

The results obtained by pellet powder far surpassed those obtained by the use of L.G.R., but the difficulties in making it led to further experiments, and these resulted in the production of what is designated "pebble" powder, which may be said to consist of lumps rather than of grains, each lump being a rough cube having a side of $\frac{5}{8}$ in. The pellet form was abandoned, it is stated, because of difficulties in the manufacture; are the difficulties in producing "pebble," it has been asked, insuperable?

The advantages of pellet and pebble powders over L.G.R. are strikingly illustrated in the following table, which gives the comparative values of the three kinds of powder:—

Description of powder	Charge.	Initial velocity, per second.	Maximum pressure per square inch.
Large grain rifle	30 lbs.	4,324 lbs.	29.8 tons.
Pellet	30 lbs.	1,338 lbs.	17.4 tons.
Pebble	35 lbs.	1,374 lbs.	15.4 tons.

From this it will be seen that our guns have been subjected to a strain nearly double of that which they will henceforth undergo, while the muzzle velocity will be increased. In these experiments the gun

used was an 8-in. smooth bore, the shot being cylinders of iron weighing 180 lbs., having a diameter of 7.995 in.

After the gunpowder is finished it has to undergo various kinds of proofs. First, the "hand proof," by which its general appearance and freeness from dust are examined. Second, "flashing" on a glass plate, which shows to a practised eye whether the incorporation is complete, and whether the powder is likely to foul the guns when fired. Third, cubing or ascertaining the weight of a cubic foot of powder. A cubic foot of Enfield rifle weighs nearly 54 lbs., while L. G. and L. G. R. weigh 56 lbs. and 60 lbs. respectively. The "pebble" is not "cubed," but its density ranges from 1.70 to 1.82. The last proof is the firing. The old method was to place 2 oz. of L. G. or 3 oz. of L. G. R. in the chamber of a mortar, and fire a solid shot of 68 lbs. The distance this ball was carried was held to be a test of the strength of the gunpowder fired. Every gunpowder maker knew the system was utterly untrustworthy, and it was only tolerated because no better method was known. Now a different and scientific method has been devised, and our English gunpowder will, it is believed, be quite equal to its requirements. The old and clumsy "cube" is to give way to the mercurial densimeter, and the mortar must yield to Captain Andrew Noble's chronoscope or to the chronograph.

Little more than a year since the Navez-Leurs' electric-ballistric apparatus was thought to meet every requirement in the proof of gunpowder, but it was quickly superseded by the chronographs of Captain Schultz and Professor Bachforth. These only measure velocities after the shot has left the gun, while the chronoscope, invented by Captain Noble, measures the time which the projectile occupies in traversing any part of the gun to the one-millionth part of a second. This instrument is briefly described as follows: A series of six hollow plugs is screwed into a gun at intervals from the shot to the muzzle. Each of these plugs passes from the outside of the gun to the surface of the bore. As the ball, when the powder has been fired, moves by the first plug, it presses a cutter which separates a wire passing through the plug to the outside of the gun. This is repeated as the projectile passes each plug. Each of the wires so divided is the primary wire of an induction coil, and as each is divided an electric spark is flashed from the secondary wires on to a corresponding thin metal disc, the edges of which are covered with white paper coated with lamp-black. These discs, which are 36 in. in diameter, rotate at about the rate of thirty revolutions a second, or about 1 in. of circumference in the one-thousandth part of a second. This inch of circumference is divided by means of a vernier into 1,000 parts, thus giving readings to the one-millionth part of a second. As the electric spark is flashed out, it is received on the edge of its disc, and burns away the lampblack, leaving a white spot, from which calculations are made.

To determine the direct pressure exerted upon the gun, Rodman's pressure gauge, and an instrument called a "crusher," are in use. The former consists of a number of plugs fitted into the bore of the gun, each of the plugs being fitted with a knife-edge and a small piece of copper. The depth to which the knife is driven into the copper, registers the pressure at that part of the gun. The "crusher "gauge is similar in principle to the Rodman, but, instead of a knife-edge cutting into copper, a solid cylinder of copper is crushed by a piston, which is set in motion by the pressure of the gas. A testing apparatus shows the force required to effect a given compression. This "crusher" gauge gives results far more satisfactory than those given by the Rodman gauge.

The writer of the article in the "Westminster Review" concludes by stating that every little while the public is startled by an account of deaths by gunpowder, and that, although he does not think any legislative action will ever make the manufacture of gunpowder a safe trade, he believes that the appointment of two inspectors thoroughly acquainted with the nature and details of the business would do much to diminish the dangers which attend the public generally, not only from gunpowder, but from all other explosive compounds used for mining purposes, and their reports, presented from time to time, might form the foundation of a new Gunpowder Act, which, while it should interfere as little as possible with the rights of manufacturers, and place few restrictions

upon their trade, should make regulations for the guidance of the makers, the sellers, and the users of all explosive compounds, whether gunpowder, fireworks, gun-cotton, percussion caps, nitroglycerine, or dynamite.

ON THE ARCHIMEDEAN SCREW FOR LIFTING WATER.

By MR. WILFRID AIRY, Assoc. Inst. C. E.

From "The Artizan."

This communication was intended to supply information regarding the best form of the Archimedean Screw, and its effect when laid at different angles of inclination to the horizon. After suggesting that the previous neglect of this subject was probably owing to the mathematical and practical difficulties attending the construction of screws in the ordinary way, viz., with the threads at right angles to the surface of the core, the author stated that he had adopted another principle of forming the spiral threads, which would simplify the work of construction and produce a more efficient machine. This was to make the spiral threads on the natural and developable system. If an annular piece of card, or tin, be wrapped upon a cylindrical core, having its edge retained in a shallow spiral groove on the surface of the core, it would naturally take up a fixed and determined position, not at right angles to the surface of the core, but inclined to it; and inclined to it at an angle depending only upon the inclination of the spiral groove on the core. The chief advantage of this spiral thread was that it could be made of a single flat piece of plate, and no work was required except to cut out an annulus, which when wrapped upon the core, gave at once the spiral surface; whereas the threads at a right angle to the surface of the core could only be constructed approximately, by using a great number of small pieces. The developable threads also produced a more efficient machine than the threads of the usual form, as was shown by reference to tabular diagrams.

The first set of experiments was made with models of screws of different spiral angles (the "spiral angle" of a screw being the inclination of a spiral line on the core to the lines parallel to the axis of the core) having only one thread apiece, and the results of these experiments were given on the diagrams; but it was easily seen that every screw ought to have as many threads as ordinary workmanship and convenience would allow. This was also shown by reference to the results of experiment; and it was concluded that to allow of easy fitting, riveting, and examination, the width of the chambers for a large screw should not be less than 18 in. on the square. This condition was used to regulate the number of threads for the models for the second set of expeiments.

The second set of experiments was made on 6 models, whose spiral angles were 20, 30, 40, 50, 60, and 74 deg.; the number of threads being varied from 4 to 1. The models were successively inclined at different angles, and the water contained by each model in its different positions was measured by a measuring glass. These experiments formed the basis of the investigation, and it was deduced from them:

(1.) That the quicker the spiral, the flatter must the machine be laid to produce its best effect.

(2.) That screws of quick spiral angle, when laid at their best angle of inclination, delivered a far greater volume of water per revolution than those of slower spiral angle when laid at their best angle of inclination.

In order to ascertain the most economical form of screw, it was necessary to investigate the loss of power due to the internal friction of the water and the external friction on the gudgeons for each machine. This was done by calculation, and the results were obtained numerically for screws of certain specified size, lifting to a height of 10 ft. The frictional drawbacks thus obtained were applied to each machine when laid at its best angle of effect, and the efficiencies of the different screws were then calculated. The result showed that the machine whose spiral angle was 30 deg. was the most economical, but that the machine whose spiral angle was 40 deg. approached it very

closely. The best angles of inclination for these two machines were respectively 25 and 30 deg. to the horizontal. In the most favorable case, the useful effect of the screw appeared at 88 per cent., and it was concluded that, after making allowance for certain small losses referred to, the useful effect of a well-constructed screw should not be less than 85 per cent. Reference was then made, by way of comparison, to other machines commonly used for low lifts, viz.: suction pumps, centrifugal pumps, open Archimedean screws, scoop wheels, chain pumps, and Persian wheels; and the paper concluded by pointing out the various advantages of the Archimedean screw, more particularly as regards its durability, simplicity, and useful effect. The communication was illustrated by the series of models from which the results were obtained, and also by a screw, 5 ft. in length, constructed on the system of threads advocated by the author. A model was likewise exhibited, to show the improvements which might be applied to obviate the defects of scoop-wheels, as at present constructed and mounted.

TRACTION ENGINE RESISTANCES.

From "Engineering."

Lieutenant Crompton, "R. E," has lately published, in the columns of a contemporary, a somewhat remarkable paper on "The Properties of Elastic Tyres." We do not know Lieutenant Crompton, neither do we know to what title the letters appended to his name refer—for, in searching the "Army List," we have found but one Lieutenant Crompton in the Royal Engineers, and we have been informed that *he* is *not* the writer of the article we have mentioned; but we should judge, from the tone of his paper, that he is a great enthusiast in the matter of india-rubber tyres. In fact, his paper mainly consists of an enumeration of the vast advantages which, according to his ideas, attend the application of such tyres to traction engines, no notice whatever being taken of the numerous drawbacks by which the use of such tyres is attended. Our own opinions of india-rubber tyres we gave plainly in December last (*vide* page 425 of our last volume), and we have not since met with any reasons for modifying the views we then expressed—views which, we need scarcely add, differ to a most important extent from those of Lieutenant Crompton. It is not this difference of views, however, that has led us to notice Lieutenant Crompton's paper here. Many of the advantages of india-rubber tyres, so plausibly urged by that gentleman, are so entirely matters of his own opinion, and are so totally unsubstantiated by definite proofs, that it would not be worth while for us to waste time in arguing on them. But, in addition to these expressions of opinion, Lieutenant Crompton makes certain definite statements concerning the rolling resistances of engines and wagons mounted on rigid and elastic-tyred wheels respectively, and as he lays down these statements authoritatively, as if they were the results of actual experience, it may be worth while to criticise some of them. We are, of course, willing to admit that over rough and uneven roads the rolling resistance of elastic-tyred wheels will be less than that of rigid wheels (and if india-rubber tyres would last for ever, and if their cost was low, they might therefore be employed on such roads with advantage); but when Lieutenant Crompton informs us that on newly broken stone the rolling resistances of elastic-tyred wheels is 110 lbs., and that of wheels with rigid tyres 440 lbs., (!) per ton of load carried, we may be excused for making a few simple calculations to verify his results. The immediate result of these calculations has been to enormously increase our respect for Messrs. Aveling and Porter's steam road rollers. We always admired these machines, and considered them excellently adapted for the work they had to perform; but we never, until we read Lieutenant Crompton's table of resistances, appreciated their enormous power-generating qualities. A few figures will explain what we mean. Messrs. Aveling and Porter's rollers are capable of travelling easily over a newly-laid road at the rate of 2½ miles per hour, or 220 ft. per minute, and, according to Lieutenant

Crompton, the power which they expend in overcoming the rolling resistances would thus be $220 \times 440 = 96.800$ ft. lbs. for each ton of their weight. But the frictional resistances of the engine, gearing, and pitch chains, etc., may certainly be taken as absorbing 15 per cent of the indicated power, and thus the latter would have to be greater than that required to overcome the rolling resistances in the proportion of 100 to 85, or, in other words, the indicated power developed must amount to $\frac{96800 \times 100}{85} = 113,882$ ft. lbs. per minute, or 3.451 horse power, for each ton of the roller's weight.

Thus it follows that if—we say *if*, mind—Lieutenant Crompton's statements are correct, a 15-ton roller must develop 51.76 indicated horse power when moving at the rate of $2\frac{1}{2}$ miles per hour. Considering that Messrs. Aveling and Porter fit each of their 15-ton rollers with a boiler and cylinder, etc., of the dimensions of their ordinary 6-horse engine, such a result as that above stated is, to say the least of it, somewhat surprising, and it will probably lead most people to suppose that Lieutenant Crompton's table of resistances requires some revision. We may further direct Lieut. Crompton's attention to the fact that London 2-horse omnibuses, weighing, loaded, over $2\frac{1}{2}$ tons, are frequently drawn over a length of newly laid roadway at the rate of 4 miles per hour, and that thus, if his data as to the rolling resistance of rigid wheels is correct, each horse must, under such circumstances, "indicate" $6\frac{1}{4}$ horse power, and exert a dead pull equal to more than half his own weight! Probably he (Lieut. Crompton, not the horse) may find this "fact" in natural history interesting. Some of Lieutenant Crompton's other statements—such, for instance, as that on soft grass land the rolling resistance of rigid wheels is $3\frac{3}{4}$ times as great as that of wheels with elastic tyres, and that on such land rigid wheels "possess practically no adhesion at all"—we may probably comment upon hereafter.

THE ATLANTIC TELEGRAPHS.

From "The Engineer."

The two English Atlantic cables have now ceased to work for some months, and the French Atlantic cable is said to be stuttering. An American journalist has not scrupled to declare that the breakdown is a "judgment" upon the two cables, which have met the fate of Ananias and Sapphira, and for the very self-same reason, namely, that their statements were often considerably in advance of the truth. Every year since they were laid there has been a breakdown of one or other of the two cables, the stoppage of communication in each case arising from preventable causes; and we pointed out in this journal at the time the cables were being deposited in the ocean bed, that the present accidents to them must of necessity occur, and could be avoided. The precautionary measures we recommended would have cost little—in fact the expense would have scarcely been felt at all by the shareholders, and would have saved them their present enormous losses.

The early publications issued by those commercially interested in the projected Atlantic telegraphs gave vivid pictures of the smooth, oozy bottom of the Atlantic from Ireland to Newfoundland, saying nothing about icebergs and a rocky bottom; they also stated that the route along which the French Atlantic cable is now working was utterly impracticable, and worthless for telegraphic purposes. On sifting the evidence from independent sources, however, and on examining standard charts, we discovered that the cable would be exposed near Newfoundland to dangers arising from the grounding of icebergs, and the rocky nature of the bed at that part of the American coast. We also discovered that the balance of evidence about the nature of the deep sea portion of the route was in favor of the truth of the statements made by the Atlantic Telegraph directors. For instance, on July 6th, 1866, we published the following information:—"In the absence of direct evidence, and with the possession of very scanty data, it seems reasonable to suppose that currents act in places upon the cable bed, but probably

with a very moderate velocity. Should such be the case there is a chance of the prolonged duration of the cable in working order. In the neighborhood of the Banks of Newfoundland it seems likely to receive the roughest usage .... The greatest difficulties in the way of the submergence of the line are found on the further half of the cable track, and although the chances are in favor of the paying out being performed successfully, they are against the maintenance of telegraphic communication for any considerable period."

In another article, published the followlowing week, we made the following statement:—"The great fact rendering it doubtful whether the cable can be maintained is that off the coast of Newfoundland, it will be subject to attacks from icebergs. These icebergs are brought down in dozens from the polar regions by the cold southward current, and they ground on the fishing banks at the exact point where the cable crosses their track." Again, on the 27th July, 1866, we said:—"The coasts of Newfoundland and Labrador not only have these inhospitable icebergs sailing round their shores, but are themselves, as a rule, rugged and precipitous, and formed of granitic and primitive rocks. The entrance to the harbor of St. John's is of this character. Where the ground is thus uneven above water, it is not unreasonable to assume that it is the same below, especially as the few soundings taken north of the Banks of Newfoundland show great irregularities in the depths. More data about this portion of the ocean bed should be obtained before an opinion can be formed as to the permanency of a cable laid thereon." Such being the facts of the case, of course common sense taught that a thick length of shore-end cable ought to be laid over this dangerous part of the track; so in the same article we said:—"Possibly future years will prove that the most lasting form of Atlantic cable is one with a very thick shore-end all the way from Heart's Content to a point to the north-east of the coast of Newfoundland." Had this simple suggestion been acted upon, and, when the cable was afterwards first fished up for repairs at this spot, had a thick length been laid all the way to the shore, the shareholders would have had a very small outlay, and saved untold thousands of pounds.

Not satisfied with giving the foregoing advice once, we did so again on August 3d, 1866, as follows:—"If the main body of the cable prove durable, the length of it in the shallow water north-east of Newfoundland is too slight, as the soundings there denote rough, uneven, and rocky ground. The ridges of the neighboring coast are of granitic and primitive rocks, running north-east and south-west; so that if the same formation prevails below water, as may reasonably be inferred, the cable crosses the rock nearly at right angles. Five miles of thick shore-end are laid off Heart's Content, but to the mouth of Trinity Bay, and across the rough ground north of the Banks of Newfoundland, the thin 1-in. cable is used. In the uncertainty whether the line could be laid or not, of course it would have been very injudicious to have made several hundred miles of thick cable for this bad portion of the route, although past experience demonstrates that this portion of the line must be thickened, when Atlantic telegraphy is proved, as we think it will be, to be a safe and reasonable subject for the investment of capital." Lastly, a warning was printed by us on July 20th, 1866, pointing out the necessity of so laying the two cables that when grappling for the one the other might not be accidentally hooked and broken.

All these things have come to pass. While the deep sea portions of the cables have all along, so far as the directors let the public know, been in good condition, the lengths close off Newfoundland have been cracking and breaking with chronometrical regularity, from the very first, and year by year cable-repairing ships have been at work on the spot, with all the regularity of the cod-fishers. And they will probably have to persevere in this interesting work until they lay down a length of good thick cable at this place. Why has the Anglo-American Telegraph Company not done this before? Is it from unwise stinginess? Is it from want of intelligent and competent engineers to advise and assist the directors? There seems to be a sad deficiency of brains somewhere.

The last breakage of the 1866 cable took

place about three months ago off the Newfoundland coast. While fishing for the faulty cable last November it is supposed that the second one was accidentally hooked and broken, so now both are silent. A vessel is now out fishing for them, but whether there is a supply of good thick cable on board we do not know; if not, the Atlantic cable fishing season will come on again next year with its usual certainty. This cable-repairing work is a difficult task, requiring the greatest engineering and naval skill; for it is obviously no easy task to keep a ship stationary over one spot, amid shifting winds and currents, while a splice is being made. Captain Blacklock has had more experience in this work than any living man; we do not know whether it is he who will repair or attempt to repair the present faults, but we trust that those attempts will be successful, and that on the way home he and the crew will not be troubled by ghosts, who, according to published statements, were very busy on board the ship on his way home from his last expedition.

Notwithstanding the shortcomings pointed out in this article, the Atlantic Telegraph directors and workers have done useful and noble work; they have not only laid good cables, but proved that in deep water they are durable. Probably as iron is quickly eaten away by seawater, they might be durable had they no iron sheathing; if so, the deep-sea cables of the future will be vastly cheaper than those of the present day.

COAL AND IRON.*

By J. S. NEWBERRY, M. D., LL. D.

From "The American Chemist."

Coal is entitled to be considered as the mainspring of our civilization. By the power developed in its combustion all the wheels of industry are kept in motion; commerce is carried with rapidity and certainty over all portions of the earth's surface, the useful metals are brought from the deep caves in which they have hidden themselves, and are purified and wrought to serve the purposes of man. By coal, night is in one sense converted into day, winter into summer, and the life of man, measured by its fruits, greatly prolonged. Wealth, with all the comforts, the luxuries, and the triumphs it brings, is its gift. Though black, sooty, and often repulsive in its aspects, it is the embodiment of a power more potent than that attributed to the Genii in Oriental tales. Its possession is, therefore, the highest material boon that can be craved by a community or nation. Coal is also not without its poetry. It has been formed under the stimulus of the sunshine of long past ages, and the light and power it holds are nothing else than such sunshine stored in this black casket, to wait the coming and serve the purposes of man. In the process of formation it composed the tissues of those strange trees that lifted their scaled trunks and waved their feathery foliage over the marshy shores of the carboniferous continent, where not only no man was, but gigantic salamanders and mail-clad fishes were the monarchs of the animated world.

On this picture, however, we have no time to dwell; our present purpose is to consider coal in its utilitarian aspect, and to show what it is, and for what it can be used.

That the assertions I have made in regard to the economic value of coal are not exaggerations, will be apparent by a glance at the present material condition of the civilized world.

Of all the nations of Europe, England is the most powerful, because she is the richest. Though occupying a group of islands insignificant in area, she has spread her power over the entire globe, and it is her boast that the sun never sets on her possessions. It is well known to the political economist that the source of England's wealth has been her manufacturing industry; and the mainspring of her industry has been her stores of coal. In this respect she enjoys a great preeminence over all the nations of Europe. The United Kingdoms have a coal area that has been reckoned at 10,000 square

* Extracted from the Report of Progress of the Geological Survey of Ohio in 1869.

miles, while, in round numbers, Belgium has 500, France 2,000, Spain 4,000, and the other nations of Europe still less. The annual coal production of Great Britain is now more than 100,000,000 tons, and a very short calculation will suffice to show what an important contribution this makes to her national wealth. The power developed in the combustion of a pound of coal, is reckoned by engineers as equal to 1,500,000 ft. lbs. The power exerted by a man of ordinary strength, during a day of labor, is about the same ; so that a pound of coal may be regarded as equivalent to a day's labor of a man. Hence, 300 lbs. will represent the labor of a man for a year. It has been estimated that 20,000,000 tons of the annual coal product of Great Britain is devoted to the development of motive power, and that this is equivalent to the labor of 133,000,000 of men. These men, in this calculation, are considered as exerting merely "brute force;" but since they may all be regarded as producers only, and not consumers—the profit on the balance of her coal product fully covering all expenses—we are safe in estimating the contribution made to the wealth of Great Britain, by her annual coal product, as equal to that of 133,000,000 of skilled operatives laboring for her enrichment.

Such being the value to a nation or community of this combustible, let us see how our nation and our State have shared in Nature's gifts.

The area of the coal-field of carboniferous age, lying within the limits of the United States, has been estimated at 150,000 sq. miles. The productive coal area of Ohio is not less than 10,000 sq. miles, or quite equal to that possessed by Great Britain, and far in excess of that of any other European nation.

I have said that the annual coal production of Great Britain is over 100,000,000 tons—a rate of expenditure of capital which is seriously alarming British economists. In Ohio the annual coal production is now about 3,000,000 tons. So it will be seen that we not only have an almost inexhaustible source of wealth in our coal fields, but that as yet we have scarcely begun to draw from this treasury. Hence, I was justified in saying, as I did, that this promised to be by far the most important source of our power and material progress; and one of the most important duties pressing upon our legislators, and on us as geologists, is, by all means in our power, to promote the rapid and intelligent development of all the industries that are to spring from this source.

In order that we may more clearly apprehend the nature and capabilities of the material which has such potency, and with which we are so richly endowed, I will briefly describe some of the varieties which it exhibits, and the uses to which they are adapted.

Coal is now considered by all chemists and geologists of any standing, as of organic origin, and it may be easily demonstrated that it has been derived from the decomposition of vegetable tissue. As we find it in the earth, it forms one of a series of carbonaceous minerals which represent but different stages in a progressive change from vegetable tissue as found in the living plant. In peat and lignite, we witness the first step in the formation of coal. *Peat* is bituminized vegetation, generally mosses and other herbaceous plants, which, under favorable circumstances, accumulates in marshes, hence called peat bogs. *Lignite* is the product of a similar change effected in woody tissue; and because it retains, to a greater or less degree, the form and structure of wood, it has received the name it bears. Peat is the product of the present period, and lignites are found in deposits of recent geological age. In the older formations, these carbonaceous accumulations, still further changed, are *bituminous coal.* Where special and local causes have operated to carry the change still farther, as where the beds of coal have been involved in the upheaval of mountains, and heat has acted upon it, it is converted into *anthracite.* Where this metamorphosis has been carried still further, the result is *graphite,* or black lead.

Most of the mineral fuels employed by the civilized nations of the world belong to the class of bituminous coals; but in our own country, up to the present time, by far the largest quantity of coal produced and consumed has been anthracite, because our beds of coal which lie nearest the seaboard, and have been longest worked, are of this character. These are, however, of the same age with our Ohio coal beds, and the peculiar phase which

the coals of Eastern Pennsylvania exhibit, is due to the fact that a portion of the great Alleghany coal field was involved in the upheaval of the Alleghany mountains, and the coal, in common with the associated rocks, was greatly metamorphosed; its gaseous matter being nearly all driven off by the great heat which attended the elevation of the mountains.

The changes which vegetable tissue has suffered in passing through the various stages I have enumerated, are not only physical but chemical. They have been carefully studied by several eminent chemists, and have been so fully explained, that they may be comprehended by any intelligent person. The *rationale* of this process may be seen at a glance by reference to the following formulæ:

Wood.		Loss.	Peat.
Carbon	49.1	− 21.50	= 27.6
Hydrogen	6.3	− 3.50	= 2.8
Oxygen	44.6	− 29.10	= 15.5

Wood.		Loss.	Lignite.
Carbon	49.1	− 18.65	= 30.45
Hydrogen	6.3	− 3.25	= 3.05
Oxygen	44.6	− 24,40	= 20.20

Lignite.		Loss.	Bituminous Coal.
Carbon	30.45	− 12 35	= 18 10
Hydrogen	3.05	− 1.85	= 1.20
Oxygen	20.20	− 18.13	= 2.07

Bituminous Coal.		Loss.	Anthracite.
Carbon	18.10	− 3.57	= 14.53
Hydrogen	1.20	− 0.93	= 0.27
Oxygen	2.07	− 1.32	= 0.65

Anthracite.		Loss.	Graphite.
Carbon	14.53	− 1.42	= 13.11
Hydrogen	0.27	− 0.14	= 0.13
Oxygen	0.65	− 0.65	= 0.0

From this table it will be seen that the change from wood tissue to peat or lignite, and from these to bituminous, thence to anthracite coal and plumbago, consists in the evolution of a portion of the carbon, hydrogen, and oxygen, leaving a constantly increasing percentage of carbon behind, until ultimately the resulting mineral consists of a portion of the original carbon of the plant with all its earthy matter. That portion of the original substance which is lost in the progressive change, escapes in the form of some hydrocarbon, as water, carburetted hydrogen, carbonic acid, petroleum, etc. The escape of these volatile compounds we see in the gases bubbling up from marshes where vegetable matter is undergoing decomposition; in the gases generated in our coal mines, and, in my judgment, in our oil springs, which always flow from strata charged with bituminous matter. By the application of heat, and with proper management, we can manufacture any of these mineral fuels from vegetable fibre at will. This has been done repeatedly, and although we cannot accurately reproduce the conditions under which these changes are effected in nature's laboratory, we can so closely imitate them as to demonstrate their character.

We find also that, under peculiar circumstances, nature has departed from her usual routine, and has locally effected all the changes I have enumerated, in a short space of time; as at Santa Fe, New Mexico, where a trap dyke has cut through cretaceous strata in which are beds of soft and nearly valueless lignite, and where over a large area this outflow of melted rock has converted this lignite into a compact and valuable anthracite. So at Los Bronces, in Sonora, triassic coals are converted into anthracite by an eruption of porphyritic rock. On Queen Charlotte's Island, south of Alaska, is a tertiary (?) lignite changed by a similar cause into the most beautiful and brilliant anthracite I have ever seen.

All the coals of Ohio belong to the group known as bituminous coals; but these exhibit very considerable diversity in their chemical and physical characters, and the different varieties are adapted to very different uses.

Following an economic classification, our coals may be described as, first, *dry, open-burning or furnace coals;* second, *cementing or coking coals;* third, *cannel coals.*

The first of these includes those that do not coke and adhere in the furnace, and are such as may be used in the raw state for the manufacture of iron.

The second group, to a greater or less degree, melt and agglutinate by heat, forming what blacksmiths term a "hollow fire." This property causes them to choke up the furnace and arrest the equal diffusion of the blast through the charge. Hence they cannot be used in the raw state for the manufacture of iron, but must be "coked." This process of coking consists in burning off the bituminous or gaseous portion; which leaves them in the condition of anthracite, except that, as this change is effected without pressure, the resulting material is cellular and

spongy. Coals of this character, when free from sulphur—their great contaminating impurity—are used for the manufacture of gas; the volatile portion, driven off in the retorts, serving the purpose of illumination, while that which remains is coke, and may be used as fuel.

The cannel coals have usually a more distinctly stratified structure, are more compact and homogeneous in texture, and contains a larger percentage of volatile matter than the others; also the gas they furnish has higher illuminating power. Hence they would be used, to the exclusion of all others, for the manufacture of gas, only that the coke which they furnish is of inferior quality. They are, therefore, for the most part, employed as household fuels—for which they are specially adapted—and, in small portions, for enriching the gas produced from coking varieties.

The marked differences exhibited by the kinds of coal I have enumerated, are doubtless due, principally, to the circumstances of their formation. The furnace coals have generally a distinctly laminated structure, and are composed of bituminous layers separated by thin partitions of a material allied to cannel, which does not coke. Hence the bitumen in them is held in cells, and cannot flow together, and give the mass a pasty, coherent character.

The cementing coals have few such partitions, but show, upon fracture, broad brilliant surfaces of pitch-like bitumen. Both these varieties are supposed to have been formed in marshes, where they were saturated, but not constantly covered by water. The cannel coals were deposited in lagoons of open water in the coal marshes, where the finely macerated vegetable tissue accumulated as carbonaceous mud. Hence they have a large percentage of hydrogen, and their gas has high illuminating power. Hence, also, the remains of shells, fishes, amphibians and crustacea, all aquatic animals, so generally found in them.

While it is true that coal is, as we have called it, the mainspring of modern civilization, it is also true that much of its value depends upon its association with iron. In the few words I have devoted to our coal deposits, I have done nothing like justice to their richness and value; and while Ohio cannot boast of an equal endowment in iron, it may at least be said that she has fully her share of this element of wealth. In most countries, certain varieties of iron ore are found associated with coal, black-band, clay-iron-stone, etc., and in these ores Ohio is richer than any of those States that share with her our great Alleghany coal-basin. Again, our coal-field is so situated, and the coal it furnishes is of such quality, that a large part of the richer crystalline ores found in other States must inevitably be brought to our territory to be smelted and manufactured.

In order that the conditions under which the production of iron is now, and is hereafter to be, carried on in Ohio, may be better understood, I will devote a few words to a description of the different varieties of iron ore found in our country, and their relation to the fuel with which they are to be smelted.

The richest of all the ores of iron is the "Magnetic oxide," which contains, when pure, 72.4 per cent. metallic iron, and 27.6 oxygen. It consists of the protoxide and sesquioxide combined, and may be recognized by its black powder and its magnetic property. This variety of ore is found in great abundance in the crystalline rocks of the Alleghany belt, in the Adirondacks, and in Canada. It is the ore brought to us under the name of Champlain ore, from the fact of its occurrence on the shores of Lake Champlain, and is that mined so extensively in Southern New York, New Jersey, and further south along the same line. From its abundance in the localities I have cited, and its proximity to the anthracite coal of Pennsylvania, this ore has formed the basis of a very large manufacture in the Eastern States, and has furnished more of the iron produced in this country than any other single variety.

As found in Canada, and along the Alleghanies, the magnetic ores are extremely prone to contain certain impurities, which injuriously affect the metal produced from them. These are principally phosphorus in phosphate of lime, and sulphur in the form of sulphide, or iron pyrites. Of these, the phosphorus renders the iron "cold short," or brittle when cold; and the sulphur "red short," or tender at a red heat. Many of these ores contain also a large percentage of titanium, by which they are rendered refractory,

and the iron made brittle. These defects in the Eastern magnetic ores almost preclude their use for the finer qualities of iron and steel, and yet they are destined to form an important element in the manufacture of iron in Ohio. Iron-making is, in one aspect, much like oil-painting, for, as the painter gets his finest effects by skilfully blending many tints, so the iron-maker can only obtain his best results by using in the furnace several varieties of ore. The iron ores of Eastern New York and Canada may, by the cheapness of return freights, be delivered within our territory at a price so low that they will continue to be used, as they now are, in considerable quantities, by our iron-smelters. Some of the Canadian ores can be furnished on the Lake shore at a very low figure, but these ores are so largely contaminated by sulphur or titanium that they are, at present, but little used. When, however, we shall have introduced the Swedish roasting furnace, which will remove, at little cost, 3 and even 4 per cent. of sulphur, we may expect these ores to be much more largely imported than they now are.

The ore next in point of richness to the magnetic, is that called "Specular iron," which consists, when pure, entirely of peroxide. This is a crystalline ore, generally having a metallic appearance, and takes its name from the speculum-like reflections from its polished surfaces. When free from foreign matter, this ore contains 70 per cent. of iron, and 30 of oxygen. Most of the Lake Superior ores are of this character, as are also those of the Iron Mountains of Missouri. To us the Lake Superior ores are of immense importance, as will be seen from the fact that at least two-thirds of all the ore mined in the Marquette district are brought to our State; and this ore constitutes the main dependence of all that great group of furnaces which have been constructed in the northern part of the State within the last 20 years. The product of the Lake Superior iron mines for 1868, was 507,813 tons; for 1869, 643,283 tons, and of this, at least $\frac{1}{3}$ is supposed to have been smelted with Ohio coal. The Lake Superior ores are almost entirely free from phosphorus, sulphur, arsenic, and titanium, the ingredients which so injuriously affect iron ores elsewhere; and the magnetic ores of Michigan, of which the supply is now known to be large, are the purest of which I have any knowledge. From these facts, it is evident that the Lake Superior iron ores are peculiarly adapted to the production of all the finer grades of iron and steel; and indeed it is the opinion of our most accomplished metallurgists that the manufacture of steel in future years, so far as this country is concerned, will be based almost exclusively upon these ores.

As I have before stated, the coals of the Alleghany coal field are superior to those of the West; and it is certain that nowhere can an abundant supply of mineral fuel suitable for smelting the Lake Superior ores, be so cheaply obtained as in Ohio. Some portion of these ores are now, and will continue to be, smelted with charcoal on the upper peninsula of Michigan, but the supply of this fuel is so limited that it will play but an insignificant part in the iron manufacture of the future.

I have already referred to the iron ores of Missouri. These have become famous through the descriptions published of the magnificent deposits of Iron Mountain, Pilot Knob, Sheppard Mountain, etc. These are specular ores of excellent quality, and are of importance to us, since they are now used to a considerable extent in the southern part of the State, and still larger quantities are destined to be brought to our coals which outcrop on the banks of the Ohio.

The ores which I have enumerated, constitute, with our native ores, the main source of supply to our furnaces. I should add, however, to this list one other variety—that which is known as the "fossil ore," a stratified red hematite, found in the Clinton group, and which forms a belt of outcrop extending, with more or less intermission, from Dodge county, Wisconsin, across a portion of Canada, entering New York at Sodus Bay, passing through Oneida county, where it has received the name of the "Clinton ore," thence running down, through Central Pennsylvania, Virginia, and East Tennessee, into Georgia and Alabama. In this latter region it is known as the "Dyestone ore," from the fact that it has been employed by the inhabitants for imparting a reddish brown tint to cloth. This Clinton ore is an anhydrous peroxide,

containing from 40 to 50 per cent. of metallic iron, and generally a notable percentage of phosphorus. Its use in Ohio has depended upon this latter quality, from the fact that it imparts a "cold-shortness" to iron made from it, and is supposed to correct the red-shortness of sulphurous iron.

DESCRIPTION OF VIADUCTS ACROSS THE ESTUARIES ON THE LINE OF THE CAMBRIAN RAILWAY.

By MR. HENRY CONYBEARE, M. Inst. C. E.

From "The Artizan."

The coast line which this section of the Cambrian Railway followed for nearly 86 miles was indented by numerous estuaries, which were crossed by viaducts having an aggregate waterway of upwards of 5,000 ft.; most of these estuaries were very shallow, and the line traversed them on timber staging; in all cases, however, the viaducts across the low-water channels were permanent constructions, with wrought-iron superstructures resting on cast-iron piers. The viaduct over the tidal water of the Dovey had an opening span of 35 ft., on the principle first used by Mr. Brunlees, M. Inst. C.E., in the viaducts in Morecambe Bay. The channel was not more than 3 ft. deep at low water of spring tides, and as it was important to complete the bridge as rapidly and as cheaply as possible, the author employed ordinary piled foundations, fixing a cast-iron splice at the top of each timber pile, and driving it with it, so that the whole length of the timber should be sunk in the bed of the channel. So placed, timber piles would last as long as cast-iron; they afforded a much cheaper foundation, and one more rapidly executed than screw piling. A similar expedient was adopted in constructing the fenders for the opening span of the Barmouth viaduct. The construction of the viaduct over the estuary of the Mawddach, at Barmouth, presented some difficulties, owing to the peculiar character of the foundation, and to the extraordinary velocity of the current at certain times of the tide. This viaduct had a water-way of 2,600 ft. The estuary extended about 10 miles inland, and at the point where the railway crossed it, was constricted to less than one-half its normal width, by the projection from Cader Idris of a craggy promontory, called Figle Fawr. The deeper water (54 ft. at ordinary spring tides) was close to the northern shore, and the northern bank, which was of basalt, shelved down almost precipitously into deep water; beyond this the bed of the channel was of sand, constantly shifting and varying in depth from 2 ft. to 8 ft. Below the sand was a bed of compact gravel from 6 ft. to 8 ft. deep; and below this again a peat bog, to a depth not passed through in the preliminary borings. The piers next the northern bank were placed on shelving rock, and were necessarily cast-iron cylinders. But the unknown depth of the peat under the other portions of the channel, rendered the employment of cylinders inapplicable for the remaining piers, and screw piles were consequently used. The bed of gravel over the peat was all that could be depended upon to carry the bridge, and as this was too thin to be loaded heavily, the spans were reduced to 40 ft.; and in order to equalize the load on the piles, and to distribute it over a larger area, the six piles of each pier were arranged in two equilateral triangular groups of three each, the upper lengths of each group forming a tripod. The diameter of the screw discs was 3 ft., and the load about 2½ tons on each square foot of their surface, which was about one-half their sustaining power; after the surface of the channel had been covered with stones, this bearing area was supplemented by discs of 4 ft. and 4 ft. 6 in. in diameter, which were bolted on to the piles and rested on the stone-work. To avoid weakening the crust of gravel on which the stability of the bridge depended, the screw discs of the piles were placed 8 ft. up the piles. The inconvenience inseparable from this mode of construction, when applied in such an exposed situation, was attributed to the fact, that the piles of which each pier was composed—though sufficiently strong collectively when the

pier was complete, and all its constituent parts firmly braced together to withstand any stress of weather—had little individual strength when standing singly, or remaining unbraced, while the pier was in process of erection. The works, therefore, were somewhat delayed by piles being broken, and the staging for fixing them was swept away during heavy gales while the piers were in progress; but there was no instance of the slightest accident occurring to a pier after the bracing was once completed.

Considerable difficulty was experienced in sinking the cylindrical piers, owing to the velocity of the current, and the works had on one occasion to be suspended for some months. The opening span was 47 ft. between the points of support, which was contracted to 36 ft. by the fenders. The description of drawbridge to be employed in closing this opening was determined by the specialties of the foundation of the pier from which it was projected, which were on hard rock, shelving abruptly in a direction transverse to the axis of the bridge. Hence a swing bridge was out of the question, and there only remained the telescope or sliding drawbridge. Of these there were two varieties, the under drawbridge and the over drawbridge. The former was devised and first employed by Mr. Brunlees, and was that adopted by the author for the opening span of the Dovey viaduct. The over drawbridge was less generally known, but one had been erected some years previously at Rhyl, and had worked satisfactorily. Irrespective of its general mechanical advantages, of working more easily, and of being lowered into position, instead of being lifted up into it and supported in it, the over drawbridge was much better adapted to the requirements of the Barmouth site, in respect to foundation, than the under drawbridge, for the latter required at least a second row of piles for the support of its sliding drawbridge, and as this had to be withdrawn between and within the supports of the contiguous bay, its width was either restricted, which in this case would have interfered with the footway alongside the railway bridge, or the intervals of the piles it slid between were unduly increased.

ADDRESS OF MR. HENRY BESSEMER BEFORE THE IRON AND STEEL INSTITUTE.

From "The Engineer."

On entering upon my duties as President of the Iron and Steel Institute, I cannot but feel deeply sensible of the honor you have conferred on me by your election; and, at the same time, I fully recognize my inability to do justice to the occasion, and must therefore entirely throw myself on your indulgence.

Among the various manufacturing industries of the world, there is, perhaps, not one possessing so absorbing an interest as the manufacture of iron, whether viewed as a source of national wealth, of social advancement, or in its purely scientific character. The history of its discovery extends far back into the night of time and is lost amid the imperfect records of incipient civilization. As time rolled on, the production of this valuable metal appears to have kept pace, and gone hand in hand with the advancement of the arts, both of peace and war, down to the period at which we have now arrived.

On the 23d of June, 1869, it was the good fortune of the members of this Institute to listen to a most interesting account of the rise and progress of the iron manufactures, delivered by the noble president in his inaugural address; an account not only touching on its ancient history, but bringing it down by successive steps to the present period. This address, as you will well remember, was also accompanied by statistics, both of the home and foreign iron trade, so complete, so interesting, and so exhaustive, as to leave no standing ground for me in the same direction. There are, however, some points of interest which have cropped up since that period which I propose to bring briefly under your notice; after which I must ask you to follow me a little way off the beaten track prescribed by

custom in addresses like the present. I say briefly, because I should not like to anticipate the more interesting details of the latest improvements in the iron and steel manufacture which we may hope to have brought before us by the authors of the various papers to be submitted to your notice.

Among the many important problems still waiting for solution in the malleable iron manufacture, is the process of mechanical puddling, a process which presents so many practical difficulties to its successful accomplishment as to have hitherto heavily taxed the inventive talent and perseverance of many able men, who, though baffled for the time, have returned again to the charge, full of energy and determination. Most of the members of the Institute had an opportunity, during their visit to Wales last summer, of seeing the highly ingenious apparatus designed by Mr. Menelaus, of Dowlais, for this purpose. That such appliances should not have accomplished all that was desired of them is in itself a standing proof of the difficult nature of the task he had taken in hand. The want of success that has hitherto awaited these efforts is the more to be regretted, because the work of the puddler is one so laborious, and so exhausting to his physical and vital powers, as to render it desirable, for every reason of humanity, that hand puddling should be superseded by mechanical force. The advances made in this direction at the works of M. de Wendell, and at other works in France, are most interesting. Through the kindness of Mr. Menelaus, the committee formed to report on this process will have an opportunity of witnessing it in operation at the Dowlais Works, as soon as the apparatus can be got into working order.

While these laudable efforts are still progressing in the mechanical department of the iron manufacture, the chemical side of the question has not been lost sight of. It will be remembered by many present that, in the early part of this century, the various qualities of the iron of different districts were considered as the simple and inevitable result of some radical difference in the iron itself, such as we meet with in different kinds of wood, and in other organic substances. The science of chemistry has, however, long dispelled these erroneous notions, and shown that the simple elementary substance, iron, is precisely the same all over the world, and that the great variety in the quality and properties of this metal, as found in commerce, depended entirely on the quantity and number of other substances retained in combination with it, and, hence, that it might be possible to produce from every kind of iron ore a pure and perfect metal. The great encouragement which the enunciation of these facts at once gave to the manufacturer, led him to study the best means of purifying and separating from iron the deleterious matters found in combination with it. These efforts have had the happiest results, although we are still very far from the ideal standard of perfection which contemplates the production of an equally pure iron from all the known ores of that metal; this much, however, has been accomplished; the rule of thumb has given way before the proofs of chemistry, and the iron manufacturer of to-day no longer believes in some occult difference in the nature of the iron he treats, but his well-ordered laboratory furnishes him daily with the quantity and quality of the deleterious matters which his raw material contains, and which, as is now well known, consist chiefly of sulphur, phosphorus, and silicon. The latter substance is, for the most part, removed in the refinery and puddling furnace, but the two former still make a determined stand, and are never, in practice, so completely eliminated as to render the metal as pure as that obtained from ores where these substances are entirely absent. It is, however, no small point gained, that we know the numbers and nature of the enemies we have to struggle with. Such knowledge is said to be half the battle, but the other half is still, I fear, the most stubborn. Among the workers in this direction is Mr. Henderson, of the United States, who proposes to remove these deleterious substances by the employment of fluoric acid, in combination with oxygen; I have, however, not yet received any information as to the results obtained by the means proposed.

A second competitor in this interesting field of research is Mr. Sherman, also an American gentleman, who has been carrying on a number of experiments at the works of Sir John Brown, at Sheffield, and at other places. The invention is, I

understand it, consists in the use of iodine, or its compounds, brought into contact with the metal in the puddling furnace, or in the Bessemer converter. This problem, on purely scientific or chemical grounds, is one of considerable interest, nor is it less so in a commercial point of view ; but under the latter aspect it resolves itself chiefly into a question of how far the low-priced quality of pig iron can be made to equal the results obtained from the purer brands, and how near the cost of the process will bring up the inferior iron to the cost of the purer qualities at present in the market. On these points I have no information that would warrant me in hazarding an opinion either one way or the other. Further experiments are, however, I understand, about to be made so as to decide these important questions ; in the meantime we cannot but wish every success to the invention, which, if attained, would be of great commercial value.

Without having at all studied the question, it would at first sight appear, that instead of employing so expensive a substance as iodine in its manufactured state, that the half-vitrified ashes of sea-weed, which are rich in iodine, might be applied direct to the iron in its first process of manufacture in the blast furnace—or, by simply charging on with the rest of the material the requisite quantity of sea-weed in its raw state, or only previously dried. The carbonate of soda, chloride of potassium, and other salts, derivable from the sea-weed would, in any case, form an excellent flux, and lessen the quantity of lime required to produce a liquid cinder. It would also appear that the ashes of sea-weed, in the form of powder, could most readily be carried by the blast through the tuyeres into the Bessemer converter or at any stage of the converting process. I have found, in my early experiments, that blowing crude American pot ashes into the metal produces a very liquid cinder, but the tuyeres are more rapidly worn than when air alone is used.

Among the most important improvements lately effected in the manufacture of steel is the development, by Sir Joseph Whitworth, of the system of casting under hydraulic pressure. The casting of large masses of steel free from air bubbles has long been a source of difficulty, owing chiefly to the fact that at the extremely high temperature of molten steel a certain quantity of oxygen is absorbed and retained by the metal so long as this high temperature is kept up, but which it cannot keep in combination when the metal is cooled down to the point at which it commences to solidify ; hence, when the fluid metal is received in a cold mould, large volumes of gas are given off, some of which becomes entangled in the solidifying mass and is there retained, forming numerous cells or honeycombs. A similar result is met with in finery iron, when it is "overblown;" carbonic oxide gas is liberated in abundance during the solidification of the plate metal, and gives rise to the peculiar cellular structure so well known. Another defect inherent in steel castings owes its origin to the crystalline structure assumed by the metal in the act of solidification. So long as the metal retains undisturbed the original crystals formed by casting, the mass is only feebly coherent, its tensile strength is less than half to which it rises when hammered or rolled. It will bend only a few degrees from the straight line without fracture, while its power of elongation is also extremely limited ; but if considerable pressure be applied while the steel is passing from the fluid to the solid state, the crystals, which would otherwise become almost independent structures, are united or welded together so perfectly at this high temperature, and in their almost plastic state, as to develop the most perfect cohesion of all parts of the mass, probably more perfect than any subsequent operation of hammering could effect. In a patent which I obtained in 1856 I described a method of casting steel under hydraulic pressure in iron moulds—a cold wrought iron plunger being forced into the semi-fluid steel at one end of the mould, through the agency of the hydraulic pressure applied to its opposite end. About the same period I had observed that in those cases where fluids gave off gaseous matters under ordinary atmospheric pressure, that they were prevented from doing so by increasing the pressure on their surfaces. A familiar example of this action is seen the instant we release the gaseous pressure by the removal of the cork from a bottle of champagne, and it occurred to me that if I subjected the fluid steel to additional

atmospheric pressure that the boiling of the metal in the mould would be prevented. Thus arose the first idea of casting under the pressure of air or gases pumped into a closed chamber of great strength, in which the mould and casting were enclosed ; but, owing to numerous engagements, these inventions were left in abeyance until attention was again called to the subject, a few years since, by Sir Joseph Whitworth, who, finding great difficulty in making steel castings free from air bubbles, and of sufficient cohesive strength for the manufacture of his guns and projectiles, hit upon the idea of subjecting the metal, while still fluid, to the action of a hydraulic plunger forced into the mould. His experiments, in connection with this system of casting, have been most successful. Indeed, I can bear witness to the extreme soundness of several large cylindrical masses, turned and bored, which were shown to me at his works, in neither of which the most minute flaw or bubble hole was visible. It was also stated that these simple castings under pressure were as strong, or even stronger than bars of hammered steel. In justice to Sir Joseph Whitworth, I feel bound to say that I have no doubt whatever but that he was wholly unaware of the existence of my previous invention at the time he brought forward his system of casting under hydraulic pressure, by which the material now known as "Whitworth metal" is produced. Certain it is that we owe to him the development and first practical application of this system of casting steel under a pressure transmitted direct to the fluid, or semi-fluid metal, by a plunger actuated by hydraulic force.

It is difficult to estimate the importance of any process by which a malleable metal, stronger than forged iron, might be readily cast at once into the desired form ; but it is just this question of form which still presents the difficulty. It will be readily understood that any plain parallel figure like an elongated shot, or a solid cylinder or ingot, may be compressed by a plunger at one end, and a tolerably uniform effect be produced throughout the mass of metal ; but it is far different with more complex forms. For instance, let us apply the same force to one end of a loam mould in which a double-throw locomotive crank is to be cast. In this case we should have two breaks in the continuity of the column pressed upon ; and even if it were possible to prevent those parts of the mould between the throws from being crushed in by the enormous pressure transmitted to the end of the crank, we should infallibly fail from another cause. The plunger would, doubtless, transmit the pressure throughout the whole mass so long as the metal remained fluid ; but this is just the period at which pressure is of little or no use as a substitute for forging ; it is when solidification and a reduction of bulk is taking place, by cooling, that the force is most needed, to prevent the formation of cavities in the central parts of the mass, and to cause that cohesion of the crystals which, in other cases, is effected by the after process of hammering. It will also be obvious that the ram would be wholly incapable of transmitting force throughout the contorted limbs of a crank axle while in the act of solidification. Hence, in this, and in hundreds of other required forms, the plunger system of transmitting pressure would prove an entire failure. There are also other insuperable difficulties in the way of this system of applying pressure to the general run of castings required in steel ; the mould for each article would have to be made of enormous strength, and be only very thinly coated on the inside with clay or loam, to prevent the crushing of these materials and the consequent distortion of the casting ; while the iron mould, having only a thin coating of yielding material, would oppose the natural contraction of the mass, which would tear itself to pieces. It, however, appears that all these difficulties may be at once overcome by simply using an ordinary mould box, and moulding the article in the common way ; a very strong hooped vessel being provided in which the moulds may be placed. The opening by which the metal is run into this vessel may then be closed by a screw plug ; an artificial atmosphere of considerable pressure may be gradually generated in the vessel by the combustion of a mixture of anthracite coal and nitrate of soda ground to fine powder, and producing an incombustible gas having any desired amount of pressure, and acting in all directions on the casting, but with no more strain on the mould than it would be subjected to under ordinary atmospheric

pressure. If by this, or any other means that may be suggested, we could obtain steel or malleable iron castings free from air bubbles and of great cohesive strength, an immense point would be gained. Those who have seen the beautiful castings in steel produced in Germany, by the Bochum Steel Company, and also those of not less merit produced by Messrs. Vicars & Co., of Sheffield, will fully appreciate the importance of giving to such castings the perfect malleability and cohesive strength of steel forgings.

Among the various improvements that have within the last few years been introduced in the manufacture of iron, few are of such magnitude and importance as the production of armor plates; a manufacture called into existence by the advances made in modern artillery. The rapidity with which manufacturers have responded to the call thus made on their skill and enterprise affords an excellent example illustrative of the way in which the engineering talent of this country seems capable of keeping pace with the ever increasing wants both of the arts of peace and war. The production of malleable iron, of the excellent quality of which these plates are made, also affords another proof of the rapid progress made in this department of our great staple manufacture.

In the early part of these remarks I proposed, with your permission, to touch on one or two subjects which, it appears to me, are matters of great importance not only to the members of the Iron and Steel Institute, but to the whole engineering profession, as well as to the public in general; and when I reflect on the thoroughly practical character of the many eminent manufacturers and engineers whom I have now the honor to address, the conviction forces itself upon me most strongly that such an organization as ours is one eminently calculated to solve many of the important practical questions, both in connection with the manufacture of iron and steel, and their employment for constructive purposes, which individuals, unaided and alone, might well shrink from grappling with. It is from the members of the Iron and Steel Institute that the world looks for a practical definition of the terms iron and steel. It is true that from a chemical point of view the line of demarcation which separates these substances is as little marked as the rainbow's hues, which melt imperceptibly into each other, leaving no part at which it may be said, here one ceases and there the other begins. Thus it is with iron and steel, which passes by almost imperceptible gradations from grey iron, through every stage of mottled and white, to hard steel, and from it to steel in its mildest form, which passes into malleable iron almost unmarked. Although admitting the truth of this view of the subject, when considered chemically, the practical man recognizes in the metal iron a substance which, in its more or less pure or alloyed state, and under its physical condition of cast or wrought iron, possesses properties so different and so anomalous, that its classification becomes both easy and natural; hence three primary divisions have everywhere been recognized, viz., cast iron, wrought iron, and steel; and allowing a certain latitude in each class, there seems no reason to dispute the propriety of such a definition. With regard to the two former, cast iron and wrought iron, their manufacture has been pursued so long in every civilized country that their nature and physical characters are well known and universally recognized; but, with reference to steel, this can scarcely be said.

In the latter part of the last century the ingenious clockmaker, Huntsman, found that steel made by the cementation of iron bars was rarely perfect enough in its structure to yield a clock spring of equal strength throughout. Unable to obtain a sufficiently reliable material, he hit upon the happy idea that the fusion of bar steel, if practicable, would furnish a far more reliable material, perfectly homogeneous in structure, and free from the numerous flaws which the accidental envelopment of wood ashes on the Swedish bar so frequently caused. Fortunately for mankind this bright idea was brought to the test of practical experiment; and, after numerous failures of every kind, Huntsman was at last enabled to construct furnaces that would furnish the necessary high temperature, and crucibles that were not destroyed at a single heat; he thus at last succeeded, by laborious efforts, in producing cast steel—the most valuable and perfect condition in which the metal iron is known. This valuable process was unprotected by

patent, and was kept a profound secret by Huntsman for many years. The way in which it at last became known is among the historical events of the past, that are better buried in oblivion.

At this period there was but little prospect of the extension of the use of cast steel to other than very exceptional purposes. Being made in crucibles, containing only from 5 lbs. to 7 lbs., its cost was very high, while difficulty of fusion at that time prevented any but extremely hard or highly carbonized steel from being made. The manufacturers of Sheffield have, however, gradually overcome these difficulties, and in the year 1851 the production of cast steel in Great Britain had risen to 1,000 tons per week; and at that time a plain square bar of 500 lbs. in weight could probably have been purchased at as low a price as £40 per ton! The great extension of the cast-steel manufacture within the last few years, its reduced cost of production, together with the facility now possessed of making it of a mild or tough quality, has brought it into competition with wrought iron for several most important uses in the arts. It is this fact which opens up the important field of inquiry to which I desire especially to direct your attention. So recent has been the application of mild cast steel to engineering structures, that the civil engineer finds himself at a loss to estimate its value as a constructive material and its applicability to the work he may have in hand. If he desires to use wrought iron, he has a thousand examples before him. He has printed tables and formulæ almost in every book he turns over, and in all this he is confirmed by numerous examples, and by his own practice and observation; but if he desires to employ steel for any new structure, be it the roof of some large building, a span of unusual length across a river, where intermediate piers are almost impracticable, or in any other case, in which he hopes by economy of weight he may obtain that in steel which he cannot hope to acomplish with a weaker material, where, under such circumstances, is he to look for the desired information? Where are the numerous tables he is wont to employ? Where the formulæ deduced from practice to aid his calculation? Where the example from which he can draw his own conclusions? It is to fill up this void, and to supply such information on the authority of the first practical men in this country, that I propose to establish proofs so well authenticated and so irrefragable as to form a sure basis for after calculation, and afford means of estimating the strength of structures, and to supply tables on which implicit reliance can be placed.

The great point, I take it, will be to make such tests comparative with iron in all cases, and under circumstances equally well adapted to show the comparative value of each material for structural purposes. This is the more necessary, because I believe that many of the tables and formulæ at present in use were made at a time when wrought iron had not arrived at so perfect a state of manufacture as that to which it has now attained. It would be, therefore, necessary to repeat every test in the wrought iron and steel of the present period in order to ascertain with precision their relative power of resistance under identical conditions, or under such special conditions as may be more favorable to either material.

Should it be thought desirable that the Iron and Steel Institute should investigate this subject, I would propose that a series of preliminary experiments should be made, showing the resistance of the different materials both to tensile and compressive force, as well as to violent concussions and long continuous strains, all of which facts could be furnished by the powerful machinery erected for this and similar purposes by Mr. David Kirkaldy, whose high position would be a sufficient guarantee of the correctness and perfect impartiality of any such report. I speak of these as preliminary tests only, because I think the members of this Institute will agree with me that it is not the simple breaking or twisting of a single bar, free at all parts except in one particular direction, that is wanted, but it is the more complex strains that we have to encounter in practice that it is desirable to ascertain and to record. Thus it would be necessary to make several beams and girders of such form and construction as will fairly represent the use to which iron and steel are applied in practice. It is in order to construct these test girders of proper proportions that I propose to make the first or preliminary experiments on the materials of which they are

constructed, and I would further propose that any errors arising from the imperfect apportioning of strength in the different parts of these girders should be corrected by reconstructing them after their weak places have been shown by a first trial, and thus arrive at a structure, as near as may be, equally strong at all points, and showing the exact amount of material necessary to withstand the tension and compression of the several parts of the structure. I will not trouble you just now with the details of the simple mode by which I propose to test these beams and girders; but I have little doubt but that they would be most satisfactorily carried out by Mr. Kirkaldy, so as to complete the whole series of tests in the most reliable form. Before quitting this subject I wish to draw your attention, briefly, to the special modes of construction to which I have before alluded, and which become necessary, because wrought iron and steel differ so much in the conditions of their manufacture as to render forms and sizes in one material easy and inexpensive, which would be almost impossible, or at least too costly, in the other. For example, in a large plate girder the upper and lower webs are usually composed of numerous pieces of plate iron riveted together in several thicknesses, entailing the labor of punching numerous holes, the employment of many rivets, and much labor of fitting together, and, in the end, accompanied by a considerable reduction in strength as compared with a solid slab of the same metal. It will at once be obvious that in the manufacture of cast steel great facility is offered in making large masses, as compared with the production of such masses of wrought iron; thus, where steel is employed for the top or bottom web of a large girder, it is evident that the simplest way would be to roll a single slab of the desired dimensions, thus avoiding the labor of cutting the plates to size, and punching and riveting them, and thus also avoiding the great loss of strength consequent on the loss of section at the rivet holes. It would therefore appear that on any comparison of the two materials for a given structure, the facility which steel affords of supplying large masses must be taken into account. Nor is this all, for steel may be made with equal facility either hard or soft, and in the upper web of a girder steel specially adapted to bear a high compressive strain may be most advantageously used. A single glance at Hodgkinson's cast-iron girders shows at once how small a top web is necessary in a material so difficult of compression as cast iron, while its weakness under a tensile strain is in like manner exhibited by the massive proportions of the lower web. Although the difference in the two qualities of steel will not allow so great a difference in the proportion of a steel girder as we see in the cast iron one, it would, I believe, be of sufficient magnitude to considerably alter both the weight and cost of the structure. This harder material might be used in all cases where compressive strain alone was used, and, in order not to complicate the manufacture by numerous qualities of steel, one special quality might be fixed on for this purpose, and be distinguished from the usual make as *steel for compression.*

It would be no less interesting to ascertain how far the properties of wrought iron and steel combined in one structure could be advantageously employed with the view of affording with a given weight, or at a given cost, the greaetst amount of stability in structures of this kind. I have hitherto spoken only of beams or girders as affording examples of the nature of the tests which I deem desirable; but it will be obvious that these researches should be so modified and conducted as to afford correct data to the ship-builder as well as to the engineer. Indeed, I believe that steel has already been somewhat largely employed, in combination, for shipbuilding, by the late Chief Constructor of the Navy, with the intention of developing a greater amount of strength with a given weight of materials.

I believe it will be found that the rate of expansion of iron and steel within the limits of atmospheric temperatures will oppose no practical obstacles to their combined use. The advantages to the manufacturers which would result from an exhaustive series of trials on a practical scale, such as I propose, would be further enhanced by the readiness with which the Board of Trade and other public bodies would thereby be induced to approve structures of steel, or steel combined with iron, the weight and dimensions of which are subject to their approval.

Before closing these remarks there is another subject which I desire to bring before your notice, because it is one on the merits and importance of which you are so well able to decide.

The great development of the mechanical arts within the last century has rendered it extremely desirable that certain uniform standards of size, or measure, should be set up, by means of which a uniformity of practice has, in many cases, resulted. Thus we owe to Sir Joseph Whitworth a series of standard gauges which have been universally adopted in engineering establishments, to the great advantage of the manufacturer and the user of the machinery in which these accurate and definite sizes of parts have been introduced. The same may be said of the Whitworth screw threads so generally employed in our mechanical workshops. But perhaps the most marked application of the employment of standard screw threads is found in the manufacture of welded iron gas pipes, from which we derive an amount of advantages which, owing to our familiarity with it is rarely appreciated to its full extent. So obviously advantageous is this system, that we happily see its principle extending from day to day, even to an entire mechanical structure, as in gun-making, where every part is made to a standard pattern, so that the possession of a few duplicate parts will enable a broken or otherwise useless rifle to be perfectly restored in a few minutes, at a cost immeasurably below that which would have been required to make a single part to order. And it must be borne in mind that this system of standard sizes not only affords great advantages to the general public, but it lessens the cost of production, by admitting of the employment of special tools and appliances for the production of these numerous pieces, which could not be employed in the chaotic state reigning in our manufactories before these principles were applied. In the early days of our railway system, the great Stephenson and his compeers had to feel their way gently in the new career they were pursuing; their engines were mere toys compared with those we now employ, and the loads they drew were small in proportion. It was therefore only necessary that they should employ a rail suitable to the traffic of the lines as then worked; but as the railway system began to develop itself, and new lines were opened, the necessity for heavier engines and greater traffic became apparent to the engineers by whom they were designed. Nor was the mere addition of size the only point studied; different modes of laying down the rail were proposed and were canvassed with great interest. Stone blocks gave way to cross wood sleepers, and these again had their rivals in longitudinal sleepers, and with them came the bridge rail and the Vignoles rail, and the double-headed rail now commonly in use. Nothing could be more natural than the way in which the profession thus glided imperceptibly into the adoption of rails of almost every imaginable variety of form and size, nor can any one be blamed for a result almost inevitable under the circumstances.

But it is now evident that there is no need in practice for this infinite variety of size and form; we know pretty accurately what is the general average traffic on a line and the weight of our engines. The work which a rail has to perform is so perfectly simple, and so clearly defined, that there cannot at the present day be any difficulty in establishing a standard rail suitable for all purposes.

Thus, suppose we take the double-headed and the Vignoles rail as representing the two classes of rails suitable for longitudinal cross sleepers, and if we make a heavy, medium, and light one of each of these types of rail, we should have a choice of six sizes that would supply all the reasonable demands of our present railway system. Taking these three standard sizes of iron rails, of each class, I would then make three other standards of steel rails, in which the table or wearing surface was identical in each case with the iron standard, but so reduced in weight per yard as to reduce its powers to resist a blow or to sustain a weight precisely equal to the iron standard, so that in all cases the iron *a b c* rails and the steel *a b c* should possess the same powers of resistance to a heavy load, or a sudden concussion. We should thus diminish the great apparent difference in price between the iron and steel rail, for it must be remembered, *that the price per mile and not the price per ton*, is the real test of the *cost of rails*. The adoption of a standard rail would afford great facilities to the manufacturer by diminishing

his stock of *rolls* and allowing him to manufacture in slack times, and to supply any sudden demands from stock. It would lessen the cost of production and afford the general advantages to the consumer and producer which have hitherto resulted in all cases from the adoption of universal or standard measures. It is difficult to imagine the state of utter confusion that would have reigned throughout our whole railway system had the gauge differed on every line to the same extent as the rails. The one instance afforded by the broad gauge is sufficient to convince us of the immense disadvantages that would have resulted from such an error, and I doubt not but should we happily arrive at a universal *a b c* standard for rails, we should in the future look back with dismay on our present chaotic state.

I therefore feel a conviction that the time has arrived when a conference with our leading railway engineers would result in the adoption of an iron and steel *a b c* standard for rails, to the great advantage of all concerned. There would, of course, be no difficulty in supplying, if required, *outside sizes* at a *higher quotation*.

In the course of these remarks, I have ventured to bring under your notice two proposals, which appear to me deserving of the attention of the Institute, and which are intimately connected with the interests of many of its members. I have done so with much diffidence, because I cannot but be aware that I am addressing many gentlemen who are far more able than myself to form a correct opinion on the subjects I have been discussing; I must, therefore, beg that you will clearly understand that I have no wish to put forward these propositions with any force as coming from the chair; indeed, I do not know that such subjects should have been broached at all in an address like the present. I feel, also, that I owe you some apology for dwelling at such length on the subject of steel, but I have felt it almost impossible to avoid doing so.

THE CONTRACTION OF THE EARTH.

By B. PEIRCE.

From "Nature."

The phenomena, which were ably presented by the distinguished geologist, Mr. Lesley, to the National Academy of Sciences, and which seem to demonstrate that the outer shell of the earth has sensibly shrunk, in some directions at least, since its original formation, naturally invite the attention of physicists to the possible causes of such a result. The most obvious cause of the shrinking of the earth is its cooling. But to shrink 2 per cent. linearly, which is the amount deduced by Mr. Lesley from the observed geological phenomena, involves a probable cooling of the whole earth of not less than 2,000 deg. Centigrade, which would require that its original temperature should be higher than would be consistent with the solidity of these shrunk strata.

Another source of change of form, which would produce shrinkages in different directions in different parts of the earth, is to be found in the diminution of oblateness arising from the diminished velocity of rotation upon the axis. Such diminution of the velocity of rotation has several years ago been shown by Mr. Ferrel, to be caused by the action of the moon in producing the tides; this is, therefore, a true cause, and it is only necessary to examine how great its amount can be, under any circumstances. This is all which is proposed in the present investigation, and the application to facts is reserved for geologists.

It is sufficient, for the present object, to regard the earth as homogeneous. Under this condition, Laplace has shown that the time of the earth's rotation could not be less than about $\frac{1}{17}$ of a day, which corresponds to a ratio of the axis of the equator to that of the pole, equal to 2.7197, and an equatorial circumference 94 per cent. greater than the present one. Such is, then, the amount of shrinking which might have taken place, if any cause could be assigned capable of producing so great a reduction of the earth's velocity. The whole surface of the earth would have been about 130 per cent. larger than at present.

But the only cause at present known which would produce a sensible reduction of the earth's velocity is the lunar action upon the tides. But in this mutual action between the moon and the earth, the common rotation area of the earth and moon must remain unchanged. The question then arises, How great a reduction of the rotation area of the earth would have passed into that of the moon? In this inquiry it may be assumed that the moon revolves in a circular orbit in the plane of the earth's equator.

Now, the moon's rotation area is 3.716 times the earth's. But if, in the origin, it had revolved just in contact with this earth, its rotation area would not have been less than 0.480 times the earth's, so that it could not have absorbed a rotation area from the earth greater than 3.236 times the earth's present rotation area, and therefore the earth's rotation area could never have exceeded 4.236 times that which it has at present. But, with the maximum velocity of rotation given by Laplace, the earth's rotation area would have been 37½ times greater than at present. It can never, therefore, have been reduced to so great an extent by the moon's action on the tides. But since, when the oblateness is small, the rotation area is nearly proportional to the velocity, and the excess of the square of the equatorial above that of the polar axis is nearly proportional to the square of the velocity, this excess may have been originally nearly 18 times as great as at present, or about 15½ per cent. of the square of the polar axis. This would correspond to a figure of the earth in which the equatorial radius would have been about 2½ per cent. greater than at present; so that it is sufficient to account for the observed phenomenon.

This peculiar form of shrinkage would produce the highest mountains at the equator, and the tendency of the mountain ranges would then be to assume the direction of the meridian. But nearer the poles the mountains would be less elevated, and would rather tend towards the direction of the parallels of latitude.

It is, next, expedient to consider the mechanical question of the loss of living force in the case of the moon's action upon the waters of the earth, and its effect upon their different motions. In this connection there are problems worthy of the attention of geometers; such as the relative motions of bodies rotating above the same vertical axis, towards which they are drawn by weights, and acting upon each other through the friction on the axis. For one of the bodies a rotating wheel may be substituted. There is also the case of two planets revolving about a primary, and acting upon each other through some form of friction.

In this way it will be seen that the planet or satellite once formed is constantly removed from the primary, and that planets tend to approach each other. It is interesting to consider whether this may not be one of the actual problems of nature.

GUNPOWDER FOR HEAVY GUNS.

From "Engineering."

The irregularities observable in the results of the proof of the 35-ton gun at Woolwich have reopened a question which was thought to have been definitely settled by the careful experiments of the Committee on Explosives. This question is the exact form and size of grain that shall be given to powder for use in our heavy guns. In an article which appeared in our journal last week, we discussed at some length the various points connected with this subject. It will, therefore, be unnecessary here to repeat them, or to do more than mention that the Committee on Explosives, under the presidency of Colonel Younghusband, R.A., have resumed their labors, with the view of solving this question. In pursuance of their purpose, they carried out some experiments at Shoeburyness on Wednesday and Thursday last week, which had an important bearing on the question at issue. The practice was intended to determine the quantity of pebble powder that ought to be used as a service charge for the new 11-in. Woolwich muzzle-loading rifled gun, as well as for guns of a somewhat smaller calibre. The new 11-in.

gun is about the same weight as the 12-in. 600-pounder, its weight being 24 tons 19 cwt. 2 qrs. The projectiles fired on the recent occasions were Palliser shells, weighing, empty, 535 lbs., and common shells brought up to the same weight with lead. The piece was mounted on a 23-ton gun wrought-iron sliding carriage, of 56½ cwt., and wrought-iron platform, fitted with hydraulic buffer, containing 12 gals. of oil, and a piston with 3 holes of $\frac{9}{10}$ in. in diameter.

The details of the practice are given in the following Table :

Table Showing the Practice with the 11-*in. Gun.*

Round.	Weight of powder charge.	Character of powder.	Projectile.	Velocity in feet per second.	Recoil.	Pressure in tons.
No.	lbs.				ft. in.	
1	70	R. L. G.....	Common shell	1102	4 1	31.9
2	70	"	Palliser "	1206	4 3½	27.6*
3	70	"	" "	1212	4 8	....
4	75	Pebble	Common "	1267	4 8	....
5	75	"	Palliser "	1234	4 8	19.7
6	75	"	" "	1234	4 6	....
7	80	"	Common "	1275	4 8	....
8	80	"	Palliser "	1217	4 7	21.7
9	80	"	" "	1276	4 9	....
10	85	"	Common "	1309	4 11	....
11	85	"	Palliser "	1301	4 10	29.6
12	85	"	" "	1308	4 11	....
13	90	"	Common "	1313	5 0	....
14	90	"	Palliser "	1308	5 0	35.0
15	90	"	" "	1338	5 1	....
16	70	R. L. G.....	" "	1197	4 6	34.5

The velocities having been taken at a distance of 75 yards from the gun, 10 ft. must be added in each case to approximate the results to muzzle velocities. The pressures recorded were taken by Captain Noble's crushers placed in a copper cap at—with the exception of No. 2—the rear end of the bore of the gun. Where the pressures are not recorded they have not yet been ascertained, the crushers having been placed at the rear of the projectiles, which have to be recovered from the sands. In round No. 2 the crusher was placed at the rear of the projectile which was afterwards recovered. The R.L.G. presented unmistakable signs of very violent action, having in round No. 1 completely crumpled up the cap which it carried out of the gun 34 yards to the front. The velocity of the projectile was exceedingly low, but this may have been owing to the fact that this was the first round fired from the gun since its proof, and there may have been influences tending to diminish the velocity. The last round of the series, fired after the gun had got into working order, and when it would be free from any such influences, offers a direct comparison with the first round. In this case the violent action of the R.L.G. powder was again apparent, the edges of the crusher cap being distorted and bent over, the crusher was disconnected from the cap and deposited in the bore of the gun a few inches from the muzzle.

To arrive at the value of the results of the experiments with the 11-in. gun, we must first refer to the behavior of the two kinds of powder in the 12-in. 600-pounder gun. From known results in this case we find 67 lbs. of the R.L.G. powder giving a muzzle velocity of 1,168 ft., and a pressure of 22 tons in the chamber, and 85 lbs. of pebble powder, giving a muzzle velocity of 1300 ft. per second, with a chamber pressure of 17 tons to the inch. In the practice with the 11-in. gun, it will be seen that the same quantity of pebble powder—85 lbs.—with a projectile 65 lbs. lighter than that used in the 12-in. gun, gave 29.6 tons pressure. So far it has been made clear that the increased length of chamber has materially increased the longitudinal pressure of the explosive gases. A comparison of the results of the R.L.G. rounds in our table with those fired with pebble powder

*Crusher placed at rear of projectile and recovered.

shows in favor of the latter, 75 lbs. of which gave only 19.7 tons pressure, as against from 31.9 to 34.5 tons with 70 lbs. of the former. Again, the 34.5 tons pressure from 70 lbs. of R.L.G. powder is only about balanced by the pressure from 90 lbs. of pebble powder, which is 35 tons, giving an excess of charge of nearly $\frac{1}{3}$ in the case of the pebble powder.

The next series of experiments was made with a 6.3 in. Palliser converted (68 pounder) gun. This was the experimental test for utilizing the heavy smooth-bore guns and carriages now in position in forts in India. The present weapon, as a smooth-bore, was an 8-in. gun, but it has been lined with a wrought-iron tube, and rifled to a 6.3 bore, and is at present the only gun of its kind. The gun was fired with L.G. and pebble powder, the pressures being taken by crushers placed in copper caps at the end of the bore. The practice is shown in the following Table:

Table Showing the Practice with the 6.3-in Gun.

Round.	Weight of powder charge.	Character of powder.	Projectile and Weight.	Velocity in feet per second.	Recoil.	Pressure in tons.
No.	lbs.				ft. in.	
1	12	L.G.	Common Shell, 68 lbs....	1412	4 5	20.8
2	12	" ..	" " " ...	1406	4 5	25.7
3	18	Pebble...	" " " ...	1527	7 1	8.9
4	18	" ...	Palliser shell 90 lbs.	1377	8 3	10.9
5	18	" ...	" " "	1352	Taut up to breeching and slight rebound.	10.8
6	17	" ...	" " "	1347		10.9
7	17	" ...	" " "	1338		10.8
8	19	" ...	" " "	1362		9.4
9	19	" ...	" " "	1387		10 0
10	22	" ...	" " "	1477	Violent recoil...	18.3

The velocities were obtained at 50 yards.

The general conclusions derivable from the foregoing Table, as well as from the results of some previous experiments made by the committee, are that the service L.G. powder gives uniform results in this converted gun, the previous experiments to which we have referred showing that 15 lbs. of pebble powder, with a 90 lbs. Palliser shell, gives a mean velocity to the projectile of 1,290 ft. per second, with a pressure on the gun of 7.8 tons. On the other hand, 15 lbs. of L.G. powder gives 1,264 ft. per second only, with a pressure of 17.5 tons. An equal charge of pebble powder thus gives 26 ft. more velocity to the heavy projectile, and reduces the pressure at the end of the bore by more than one-half. We may also observe that in the previous series of experiments to which we have referred, the detailed results of which are before us, 20 lbs. of pebble powder gives a 90 lbs. Palliser shell a mean muzzle velocity of 1,445 ft., with a mean pressure of 12.9 tons. It is therefore possible that by using pebble powder we shall increase the velocity of the projectile by 180 ft. per second, and yet reduce the pressure by $\frac{1}{3}$ as compared with the battering charge of L.G. powder, which was fixed at 15 lbs. L.G. with a 90 lbs. projectile when the gun was proved.

The further testing of this 6.3 in. gun for range and accuracy is being carried out, and upon the termination of the trials, if successful, it is probable that 100 of these guns will be ordered forthwith for the Indian Government. The results obtained as regards the pebble powder show it to be far superior to the powder in ordinary use for heavy guns, although we are inclined to think that a smaller kind of pellet powder—that of $\frac{2}{3}$ in. diameter, and $\frac{9}{16}$ in. deep, cylindrically shaped and with convex ends—would produce still better results. At any rate we presume the Committee on Explosives intend to give this powder, which they can obtain from Hounslow, a fair trial before they conclude their labors.

GOLD OF NEW ZEALAND.—The yield of gold for the year 1870, shows an increase of 20,000 oz. over the preceding two years.

A SINGLE-RAIL TRAMWAY.

From "The Artizan."

In thinly-peopled and mountainous countries, and especially in many parts of Turkey, the want of roads for internal communication is the great difficulty in the way of national progress. It is also a difficulty well-nigh insurmountable by the methods to which we are accustomed in the more favored parts of Europe, because there is no capital available for the purpose of making communications that would have to create their own traffic, and that would probably ruin the owners before they had done so. For example, about ten years ago, a road was made from Beyrouth to Damascus, and upon this there is not only not a single native wagon running, but the muleteers and camel drivers take the old break-neck track by choice, because it is shorter from point to point, and is free from the trifling toll which is charged on the highway. Moreover, in such countries the value of an ordinary road is much diminished by the inevitable steepness of the gradients, which render it necessary that a wagon could carry but a small load. A carriage road is now being constructed, at a vast expense, between Alexandretta and Aleppo; and seems likely to be as little traversed as that to Damascus. It is being carried through the pass of Beilan; and, in order to obtain even tolerable inclines, a distance which is only 70 miles by mule tract will be increased to more than 100 by the new road. Mule and camel drivers will certainly not use it, more especially as it is badly supplied with water; and as the steepest gradient will be 1 in $7\frac{3}{4}$, it is difficult to conceive that wheel traffic can ever become a source of profit. A railway on the European system would be simply impracticable. Water and fuel are scarce, skilled labor is expensive and would have to be imported, the country is very difficult, and the whole value of the transport to and fro is now about £62,000 a year. At £10,000 a mile the cost of constructing a railway would be a million sterling; and, when working expenses were paid, little would remain for the shareholders. Such a line may possibly be needed hereafter as a portion of a route to India, through Alexandretta and Aleppo, to the Euphrates, and thence to Bagdad, and, as it would pass through a fine grain country, it may eventually be in itself profitable. The present need, however, is to provide a means of traffic not much in excess of the actual or probable demand, and suited to the wants of a country in which railroads are impossible from their cost, in which roads are useless because the natives find that carriages do not pay, and in which there can be no canals, because water will not run up hill. In the face of these conditions Mr. J. L. Hadden, C.E., has devised a single-rail tramway for conveyances, of which he gives the following description:—

"Imagine a bicycle let into a longitudinal aperture in the centre of the bottom of a cart, and the cart nearly touching the ground, so that only about 6 in. of the wheels would be visible; next, a kind of balancing pole run through the sides of the cart at right angles to the single rail on which the bicycle is to run. The 2 ends of the pole are to project about 3 ft. on either side of the cart, and rest upon, and be harnessed to, the backs of 2 mules. The animals will thus be 1 at each side of the load, instead of being in front in the ordinary way. It would be impossible for the cart to turn over, because, in order to do so, it would have to force one mule to the ground and to lift the other into the air; and, moreover, as its floor would only be 6 in. above the rail, an overtip would be of no account. All the weight in the cart, if evenly distributed, would bear upon the rail, and the animals, having no load on their backs, would be able to exert considerable traction power."

Mr. Hadden thinks it an incidental advantage that with such a tramway the muleteers would be compelled to keep the appointed way, instead of leaving it, as they now do, by side tracks that enable them to avoid toll bars; but, at the same time, he proposes to give the wheels broad double flanges, so that in case of need the carts would run upon any good road. He states that responsible contractors are prepared to lay his single line, with 30 lbs. rails and De Bergne's pot sleepers, at a cost of £450 per mile, all sidings included.

Mr. Hadden does not consider that the utility of his invention will be limited by the precise conditions that first called for it. He not only suggests its employment for military purposes, but also for tramways in large cities; and he says that, where space is very valuable, a horse or mule on only one side of the cart would be sufficient. In towns, on bridges and other important places, the rail might for a short distance be dispensed with; and passenger vehicles should be fitted with small friction wheels on either side, so that, if a horse should fall down, the balance of the carriage would remain undisturbed.

TELEGRAPH COMMUNICATION WITH INDIA.

From "The Engineer."

In the face of existing political combinations, and the expectation which appears to be pretty generally entertained regarding the intentions of Russia with reference to Turkey, the subject of our existing means of telegraphic communication with India assumes a greater importance than has hitherto attached to it. At present there exist three routes by which messages may be sent, two of which, forming the principal routes of communication, meet at Bushire, and thence transmit their messages to India by the Persian Gulf cable between Bushire and Kurrachee, whilst the third route is *via* the Mediterranean and Red Sea, and thence by a deep-sea cable between Aden and Bombay. It was not until the year 1858 that any practical schemes were proposed for establishing telegraphic communication between England and India, although so far back as 1855, Mr. Lionel Gisborne applied to Messrs. Glass, Elliott & Co. for information to enable him to prepare estimates for the carrying out of a telegraphic line to the East. Shortly after this, concessions were obtained from the Sultan, which were made over to the Red Sea Telegraph Company, for laying a line between Alexandria and Aden. The capital was fixed at £800,000, upon which sum the English Government guaranteed interest at the rate of 4½ per cent. for 50 years. The construction of the cable was intrusted to Messrs. Newall & Co. The line was laid, and messages were actually transmitted by this route; but after a short period the signals failed, and all attempts to restore the communication for any length of time proved fruitless. This line has, however, recently been restored, and it is connected from Aden with Bombay by means of a deep-sea cable, and from Alexandria through the Mediterranean with Malta, and thence, *via* Gibraltar and Lisbon, with Falmouth. Direct communication by this line is also available through France and Italy to Malta. The whole line by this route, therefore, consists of an alternative land and submarine line to Malta, a submarine line thence to Alexandria, a land line across the Isthmus of Suez, and a submarine line from Suez to Bombay. It must be admitted that hitherto this line has not attracted so much of the Anglo-Indian traffic as its importance from a political point of view warranted its promoters in expecting it would receive. The other lines are known as the Russian route and the Turkish route, both joining at Bushire in the Persian Gulf, whence two submarine lines extend to Gwadur, and alternative land and submarine lines thence to Kurrachee.

The route *via* Russia consists of a double line from London to Teheran, passing through Circassia and Georgia, belonging to the Indo-European Telegraph Company; a line through Persia, belonging to the Persian Government, but worked by British officers, passing through Ispahan and Shiraz to Bushire, where it joins the Persian Gulf line. It will thus be seen that the communication between England and India by this route is entirely under the command of Russia, and might at any time be interrupted in the event of that nation desiring to interfere with it. Any one who may have watched the movements of Russia in the East, and her more recent intervention with reference to Cashmere, can hardly fail to detect the continuance at the present day of her ancient policy with regard to our Eastern possessions. The route *via* Turkey is approached by five lines from London to the Turkish frontier. Their direction is as

follows:—(1) From London to Turkey, *via* Holland and the Austro-Germanic Union; (2) from London to Turkey, *via* Belgium and the Austro-Germanic Union; (3) from London to Turkey, *via* France and the Austro-Germanic Union; (4) from London to Turkey, *via* France, Switzerland, Austria and Hungary; (5) from London to Turkey, *via* France and Italy.

Fom the Turkish frontier the lines converge to Constantinople, when a special line runs *via* Bagdad to Fao, and there joins the submarine line of the Indian Government through the Persian Gulf. These lines, are not likely to be interfered with by any power desiring for its own political purposes to interrupt free communication between England and India, so far as the lines through Europe are concerned; but it is clear that by cutting the line at Constantinople the route through Turkey would be practically closed, and all the alternative lines through Europe be rendered useless. In the absence of united European interference it is clear that the power of closing this telegraph route to India is also in the hands of Russia, with power to exercise it at her will.

There remains, then, only the third, or Red Sea route, which could be relied upon in the event of any attempt on the part of Russia to seize our Indian possessions, or even to create a diversion in India with the view of weakening our powers of interference in European—possibly Turkish—affairs. Under these circumstances it may be asked—is it wise that we should be content with a single line of telegraph as our only sure means of communication with India in the event of certain not improbable contingencies, especially when an alternative line might be established with the greatest ease by the addition of a short submarine cable between Alexandria and Seleucia, at the north-east corner of the Mediterranean Sea, and thence by a short line to Aleppo, joining the existing route to Bagdad and the Persian Gulf? It is true that a land line exists from Alexandria to Cairo, and from the latter place along the eastern coast of the Mediterranean past Jerusalem, Tripoli, and Aleppo, to Diarbekir; but the objection to this is that it is not entirely in English hands, as any line between England and India should be throughout its whole length.

Now that the question of the Euphrates Valley route to India is again being revived—and its establishment has already been too long delayed—the proposed new telegraph would follow the line of the Euphrates river from Aleppo as far as Babylon, where it would join the existing line to Basra and the Persian Gulf, instead of following the valley of the Tigris, which is the course of the existing line from Constantinople. It is not probable that any danger of interruption of the Russian and Turkish lines will, so far as Russia is concerned, be allowed to be anticipated by England by reason of any premature action of hostility on her part; but, nevertheless, any precaution by England to secure her communications with India in the face of any contingencies, cannot but be deemed a wise policy, and any expenditure incurred for such a purpose would certainly not be deemed an act of extravagance, even if the necessity for it be not absolutely justified by future events.

* * * * * *

There are, it appears, already two parties in the field endeavoring to obtain concessions from the Turkish Government, viz., Mr. W. P. Andrew, Chairman of the Sind and Delhi Railway, for the construction of a line *via* the Euphrates; and Messrs. Waring Brothers, who are anxious for permission to survey for a line of railway along the valley of the Tigris, following, as will be seen, the route of the telegraphic lines between Turkey and Persia. The importance of maintaining the integrity of our telegraphic communications with India by this route cannot well be overestimated, and with the view of rendering it more perfect a second cable was laid down the Persian Gulf in October, 1869, between Jashk and Bushire, by Mr. Latimer Clark. The cable was manufactured in England in the summer of 1868, chiefly under the superintendence of Mr. F. C. Webb, and the laying of it was superintended by Mr. George Preece, under the direction of Mr. Clark himself. The total length of cable shipped from England was 535¼ miles, and the length paid out 504.39 knots, which was made up as follows:—

Shore end at Jashk	3 622
Shore end at Bushire	10.260
Main cable	490 508
Total	504.390

The distance measured along the course is 496.5 miles.

The first Persian Gulf cable, which is of gutta-percha, maintains its original resistance of about 400 megohms per knot, but the second cable, being of Hooper's india-rubber core, gives a resistance of 1,704 megohms per knot, the insulation, in both cases, being measured after one minute's electrification.

ON A VESSEL IN MOTION, AND WHAT BECOMES OF THE WATER SHE DISTURBS.

By HENRY RANSFORD, Esq., Associate.

From the "Journal of the Society of Arts."

In considering the subject, an important difference between solids and fluids must not be overlooked: it is this, in forcing a solid into another solid the particles are frequently compressed together, without altering the external form of the bodies, as driving a post into hard ground, or a nail into a block of wood; but, water being incompressible, a body forced through it, floating partly above and below the surface, or a solid let down into it, alters the form, and in either case that can only be done by raising the surface; and, unimportant as this proposition may seem at first sight, it is a principle that cannot be set aside; and, although witnessed by many every day, yet in regard to its real effect on the movement of ships it has not yet been duly considered. Another great difference between solids and fluids to be considered in the movement of vessels is, that the particles of the latter so readily communicate motion one to another without materially altering their position; thus it is a common saying with seamen, when speaking of a fast steamer, to say "her bow is so sharp, that she does not raise even a ripple before her," not considering that a great displacement and consequent movement of water to the surface somewhere has taken place, but which, being some distance ahead, or obscured by the motion of the waves, they have not perceived.

To observe the effects on water by a vessel in motion requires peculiar opportunities, that rarely occur to a sailor or persons interested in this difficult problem; it can only be seen perfectly by the side of a river, when a steamer is passing, and the surface of a glassy smoothness, and in the greatest perfection, morning or evening, when the sun is not very high above the horizon, and the tide does not cover all the shingle. If a person will then take his stand and watch a steamer approaching, he will see a wave advancing a little ahead of her, and spreading out in a curve that reaches the shore. Selecting a large pebble close to the water's edge, or driving in a small stick as a mark, he will see, as the wave approaches, the water rises and covers his mark. The wave having passed on, the water subsides, and then recedes quite as much below as it had risen above the previous level (like a stream running towards the steamer); then in a few seconds comes another wave, rising fully as high as the first one, followed by several smaller ones, which diminish in size, until the surface of the water again subsides to the same condition as before the passing of the steamer.

I was first struck by the receding of the water behind the first wave below its previous level, and was soon convinced that not merely a carrier wave had passed along the surface, but that the steamer had set in motion a stratum of water the whole distance between her bow and the advancing wave—that is, the particles of water communicated motion one to another from the bow, until they rose as a wave above the surface, which, on losing the thrust of the stratum as the boat advanced, commenced to spread or subside, but I could not at all account for the receding of the water after the passing of the wave. I at once commenced to observe closely the various kinds of craft passing up and down the river, and the effects produced when they were moving with the tide, against it, or in still water, and soon found the results were the same, but differing according to the state of the tide and the build and speed of the ves-

sels. All bluff bows similar to barges (when being towed) raised a wave very close immediately in front of them with very little spread, the effect of which on a vessel would be similar to a wheel of a cart sinking in soft ground. Ordinary bows sent the waves further ahead with an expanding curve, and the sharper the bow the wider the arc, thus increasing the distance from the wave to the bow, consequently lessening the resistance of the displaced water sent to the surface; and I observed the wave of displacement (as I term it) invariably travelled at the same rate as the vessel, irrespective of the depth of the water, quickly subsiding when a steamer stopped at a landing stage, and commencing as soon as the boat started again.

After referring to some experiments on the Erie Canal, he said:—These observations took a long time to note before feeling satisfied as to their correctness, and the invariable effect on the water. The inference that I at length drew from this accumulation of facts was, that all bows strike the water at a right angle from the plane of their curve; consequently what is considered an ordinary good bow, strikes the water with a downward as well as a side force, thus giving the particles or stratum of water, when first set in motion, a partially downward direction; then moving upwards in a curved line (the curve depending on the resistance received) until a wave is forced up on the surface, equal in bulk to the displacement, between the stem and the extreme beam of the vessel. A sharp bow striking the water more laterally than downwards, the wave of displacement does not rise to the surface so near the vessel as in the former case. The resistance not being so great from having less curve before it rises, it has a longer inclined plane (if I may so term it) to move on in its upward progress. It was evident that the following waves flowed on to fill up in some way the space left by the forward movement of the vessel; but it was a long time before I could account for the receding of the water on the shore, behind the wave of displacement. Close observation, on very calm mornings, at length showed me there was an evident depression of the surface of the water, commencing alongside the steamers, and extending towards the shore. Reasoning on this fact, I perceived it was caused by the water close to the vessel's side sinking down to occupy the space she was leaving. A screw steamer shows this far plainer than one with paddle-wheels. One fact, clearly proving the displaced water is first forced downwards by an ordinary bow before it rises, is this: a steamer, say between Hammersmith and Kew, goes slower directly she gets into shallow water. The men on board say "she drags;" the real truth is, the stratum set in motion by the bow strikes the bottom, and, instead of curving gradually upwards as in deep water, has considerable reaction against the bow, causing the vessel's head to rise and her stern to drop. Judging from these observations, it appears that what causes one ship to sail faster than another—other things being equal—is the shape of bow, which forces the water she displaces laterally, rather than downwards; for, action and reaction being alike, water forced downwards against water of greater resistance reacts against the bows, and consequently the more lateral the thrust, so much less will be the reaction; because the water is only forced against water of the same pressure, and the wave of displacement rises more easily to the surface. Now the displacement by the bow, and the sinking down of the water which fills up the space the vessel is leaving, must be simultaneous movements, and the particles of water in each case must communicate motion to those next to them, at the same velocity; it follows, that so far as the wave of displacement would extend on either side, and so fast as it would travel, just so far and so fast would also the particles of water be affected that are set in motion, to fill up the space the vessel is leaving; consequently, the receding on the shore is the action of the natural law of fluids filling up the space the vessel is leaving. It seems impossible that the space a vessel is leaving can be filled up in any other way than by the water in contact with the sides sinking down to occupy the space; the idea that the water comes up somehow from below, is surely opposed to the law of fluids. I ask what power rises or lifts it up? what water takes its place? I leave it to wiser heads to determine, but I believe it may be accepted as an axiom, that the limit to the speed of a steamboat, however powerful the engines, is the rate at which water

will flow in to fill up the space she leaves; and further, that the following must be recognized as laws in hydrostatics, viz., any ship or vessel floating in water can only move through the same by forcing to the surface a body of water of equal breadth and depth to its immersed midship section; and the bows of all ships in motion impel the water they displace at a right angle to the plane of their curve.

RAINFALL AND WATER SUPPLIES.

From "The Mechanics' Magazine.

That the water supply of towns has a very close connection with the average rainfall in the adjoining districts, is a fact too patent to require corroboration. The question may then be asked, is the rainfall year by year sufficient to afford a proper supply of water to the inhabitants of any given locality? That is just the point we purpose to consider in the present article. In other words, is the natural supply of water equal to the natural and artificial demand for it? It may be premised, as a tacit assent to the circumstance that the rainfall is supposed to yield the quantity required, that the first duty of an engineer who is called upon to design water-works for a town is to ascertain in a very careful and accurate manner the average rainfall of the neighborhood. Upon this he bases his calculations. It becomes therefore a very important detail to determine what the demand is likely to be, for not only will the supply be thereby regulated, but the cost of the reservoirs and other works be proportionately increased or diminished. The quantity of water necessary to meet the requirements of a town is usually stated at so many gallons per head per diem, and in many, in fact in all cases, there is very little attempt made to reduce this to a reasonable minimum; but, on the contrary, to raise it to as high a maximum as possible. There are very few water-works of any pretensions to magnitude which do not profess to give over 30 gallons per diem for each item of the population, and the actual quantity used is frequently very much in excess of this. It is unnecessary to mention that the waste of water in all large towns is notorious, and is one of those crying evils that ought to be stopped without any ceremony whatever. Next to air, water is the element most essential to life, and although it is a penal offence to wilfully allow it to run to waste, either by negligence or defective piping and cocks; yet from the want of adequate supervision, the enactment is a complete dead letter. As may be expected, engineers differ in their estimate of the quantity of water that is requisite for the supply of towns. It has been stated by Mr. Hawksley that from 16 to 17 gallons per head per diem would be an ample allowance, provided none were wasted. This quantity, which it must be borne in mind includes all that is required for trade purposes, appears at first sight a very low estimate. But this is only by comparison with the larger allowance, which is swelled by a liberal percentage expressly for waste. The proposition is apparently accepted, that there must be an unavoidable enormous loss of water, and that instead of it being practicable to check this and keep it within narrow limits, the only alternative is to allow for it. Instead of grappling with the evil and overcoming it, the easier but more reprehensible course is adopted of quietly sitting down under it, and making the best of it. Consequently all the necessary works of construction are on a much more extensive scale than that which would suffice for the purpose were that due regard to economy displayed which ought to characterize the treatment and use of so valuable a fluid. Another serious disadvantage arises from this excessive and costly liberality. In order to supply a large town the resources of the various catchment basins and drainage area are taxed to the utmost, and thus it frequently happens that while one town is lavishly provided with water, another in its neighborhood is very badly off for that element. The source that with proper care and the proper restrictions would furnish an adequate quantity for both towns is impounded solely for the benefit of the one.

As the quantity of water that may be

procurable for the supply of a town depends upon that which can be collected from the gathering ground, and as the latter in their turn depend upon the rainfall, the determination of the last mentioned is the real point at issue. This is of an exceedingly varying nature. The rainfall will vary with the locality, the climate, the altitude of the place where the observations are made, and also with its aspect with respect to the sun. As an example, the annual rainfall in the high gathering grounds of the Severn is estimated to be as much as seven times that in the lower situated lands of Essex. One would naturally conclude that it would be an easier matter to supply the towns with water in the former than in the latter district, but this is by no means an inevitable sequence. A very heavy annual rainfall does not necessarily imply a very large supply available for human consumption. The rain must be first caught and impounded before it can be utilized, and the quantity which can thus be collected is materially influenced by the geological nature of the gathering grounds. After rain has fallen it disposes of itself in three ways—part of it runs off, part is absorbed in the ground, and the rest is evaporated. This last part may be regarded under the same circumstances pretty nearly as a constant. The part that runs off is that most readily collected, although there is no doubt that a considerable percentage of that which is absorbed or percolated can be utilized by proper means. Rain, if not otherwise intercepted, will run off very rapidly into the nearest streams, if the inclination of the ground upon which it falls be very steep, or if it be of a rocky character. On the other hand, should it be of the nature of a table-land, a large quantity will be conveyed away by percolation and absorption. Some of this, especially if the land be insufficiently drained, as is generally the case, will find its way into springs and watercourses, and can be ultimately utilized. Again it is readily perceived that after a long continued rainfall, land that may be most prone to absorption will at length become so completely saturated or soaked that it will refuse to absorb any more or allow it to percolate through it. Under these circumstances the rain will either flow off it or remain on the surface and convert it into a marsh. If the land be flat and undrained the latter consequence is inevitable. There is another point to be borne in mind regarding the percolation and absorption of the rain water. A large quantity of it falling upon ground of this character may percolate through the overlying strata until it reaches one of an impermeable description. There it will remain impounded in the natural reservoir until it be "tapped" from above. The theory of well-sinking is founded upon the supposed existence at a certain depth of water-bearing strata of this nature, and the borings are carried down until the stratum be struck. Geology is the chief guide to works like these, but geology is nevertheless sometimes at fault. Many wells have been sunk hundreds of feet in depth, and after a large outlay of money the result has been very much below what was anticipated, and sometimes after sinking and boring until both money and patience were exhausted, the further prosecution of the undertaking had to be abandoned.

It is clear from what has been already stated that a very considerable discrepancy may and does exist between the amount of the rainfall and the quantity that can be be rendered available for consumption. If the whole of the rainfall could be caught and impounded, then the maximum utilization of it would be effected. Having shown that the original quantity of rain falling upon any given district suffers a considerable diminution before it is impounded, it may not be out of place to remark that the quality likewise is very much altered. Without going into extremes, water may be divided into two classes, hard and soft. The character or nature of these may remain constant, while their actual condition may vary. It is quite possible to have a pure hard or soft water and an impure one. Water may percolate or infiltrate through certain strata, which may have a purifying effect upon it. They may, in fact, act in some instances as a complete filter or strainer to the water, and discharge it in a very clear and pure condition. This property is possessed in an eminent degree by the sandstones, and schistose rocks are also favorable to the supply of good water. There are few gathering grounds which are throughout their whole area equally favorable to

the collection of water. If, for instance, a large portion of one be of an agricultural character the rain water flowing off is sure to be charged with manure to a greater or less extent. Similarly the existence of mineral deposits will affect the purity of the water. In estimating, therefore, the yield of gathering grounds all these circumstances must be taken fully into account, thus affording another proof that the whole of the rainfall cannot be included in the proposed supply for a town. There is still another important detail to be carefully attended to before the rainfall can be depended upon as a basis of calculation for a water supply. It is well known that the annual rainfall varies considerably, and, what is more to the point, there is nearly always a series of wet and a series of dry years consecutively.

A glance at a diagram of successive annual rainfalls, extending over a period of 20 or 30 years, will prove that it is a very rare circumstance for the maximum to be followed immediately by the minimum fall. There are, it is true, a good many jumps in the scale, but there is, nevertheless, a rough gradation from the highest to the lowest. Keeping in view, therefore, this annual variation, the question to be determined is, which particular rainfall or series of rainfalls is to be taken as the datum for basing the calculations upon. There is some diversity among engineers on this matter; many assume the driest year as the safest standard, but this is evincing, perhaps, an excess of caution. An average of the 3 driest years is a perfectly reliable datum. Intimately connected with this estimate is that of storage. It is well known that if a tenth part of the rainfall that finds its way first into rivers and streams and thence into the sea were impounded and stored, so that the superabundance of one year should counterbalance the deficiency of another, there would be no such thing as a drought. It would be impossible to build artificial reservoirs of sufficient magnitude for the purpose; but even if some means were adopted for retaining it in the ground in a water-bearing stratum, it would be ultimately of service, as it would serve to feed springs and wells. As it is, it is lost for ever. It is not like the water which is evaporated, which is recoverable as it is taken up by the clouds, and returned to the earth at a future period. But the sea restores nothing, and the conversion of the fresh into salt water precludes all possibility of its future utilization.

ON SOME NEW ENGLAND WATERS.

By S. DANA HAYES.

From "The American Chemist."

An unprecedented drought, of nearly 8 months, in this part of the country, has been the means of interesting many cities and towns, as well as individuals, in the subject of water-supply and its sources. It is customary, before introducing water, for the local authorities to employ engineers first, then obtain estimates and consult with citizens; the engineer naturally acts as a general adviser for his employers in such cases, and although I can bear witness that the majority of engineers recognize the great importance of previously analyzing waters intended for distribution in cities and towns, still there are instances where it has been entirely neglected. And the engineer is not always blamable, as, for instance, when he finds a water that tastes and smells badly, but which the analyst tells him does not contain any more grains of impurities in a gallon than one which he finds sensibly better, he does not understand why the smell and taste do not "weigh something." In this connection, the case of Cochituate water in 1854* is often cited, when it tasted and smelled of fish-oil (from crustacea in a peculiar condition), and was quite offensive; but the weight of extraneous impurity did not increase enough to turn the analyst's balance, and no oil could be seen in the water without a microscope.

But when the chemist is employed, and gives as much time to investigating the *kind* of organic matters present in waters submitted to him as is occupied in an-

*Proceedings American Academy of Arts and Sciences.

alyzing the mineral constituents, his results are of greater importance to the citizens as well as engineers, and often answer questions that can be decided in no other way.

I have analyzed many New England waters from a great variety of sources, and would like to place the ultimate results yielded by some of them on record in your valuable journal.

Table, showing the weight of impurities, in grains, in one United States Gallon, 231 cubic inches, of different waters.

No.	SOURCE.	Mineral matter.	Organic Matter.	Sotal Solids.
	MAINE:			
1	Pure spring near Auburn	0 85	0.13	1 98
2	Spring on Cape Elizabeth	7.40	2.21	9 60
3	Wells in Portland (average of four)	13.35	5.13	18.48
	NEW HAMPSHIRE:			
4	Merrimac River at Manchester (drainage)	2.96	2.60	5.50
5	" " at Lowell Mass	1.80	0.11	1.91
6	Massabesic Lake, near Manchester	1 16	1.66	2 82
7	Hotel well on Rye beach	6.08	2.43	8.51
	VERMONT:			
8	Mineral springs near St. Albans (average of seven)	15.24	1.25	16.49
9	" " at Gilford, (chalybeate)	25 27	1.65	26.92
10	" " at Brunswick	77.79	2.33	80.12
11	" " at Danby	7 19	0.91	8.10
	MASSACHUSETTS:			
12	Cochituate, Boston, February, 1871	2.37	0.83	3.20
13	Mystic, Charlestown, February, 1871	3.96	1.72	5.68
14	Jamaica Pond, Roxbury, 1867	2.41	1.36	3.77
15	Connecticut River at Holyoak (low water)	1.81	1.39	3.20
16	Saugus River, Lynn	3.12	2.40	5.52
17	Flax Pond, Lynn, (drainage)	2.24	1.84	4.08
18	Horn Pond Woburn	3.85	1 59	5.44
19	Locomotive supply, Taunton	4.37	2.03	6.40
20	Artesian well, Dedham	4.08	1.11	5.19
21	Wells in Woburn (average of four)	51.52	4.60	56.12
22	" Lynn (average of six)	19.27	4.23	23 50
23	Well on Cape Cod	10.01	2.41	12 42
24	Old Artesian well, Boston (reopened in 1871)	54.35	1.85	55.20
25	Brewery Spring, Boston	13.68	1.68	15.36
26	Dirty Brook, Boston(drainage)	9.44	12.48	21.92
27	Salt-water well	....	....	2082 0

No. 1 was supposed to be a "mineral water" by its owners.

Nos. 4 and 5 illustrate the natural purification of river-waters.

Nos. 12 and 13 were drawn from service-pipes in the respective cities.

No. 15 was perfectly clear, colorless, and apparently pure; but it contained vegetable extract that separated as a yellow semi-resinous body, when the water was brought in contact with chlorine, in the bleaching liquor of a cotton factory; there was no iron in this deposit.

No. 19 is not injurious for locomotive boilers; but No. 20 is one of the most corrosive waters that I have seen; it contains sulphur compounds, and had destroyed 2 boilers before being analyzed.

No. 21. Two of these waters contained, besides much salt, an uncommonly large proportion of nitrates, and corroded lead pipes very rapidly.

No. 22. One of these contained 5.96 grains of carbonate of zinc, from the service-pipes used in a dwelling-house.

No. 24 is an old omnibus stable well that had been covered for more than 20 years. Several thousand gallons were pumped ont before the sample was take for analysis.

No. 25 supplies water for one of the favorite ales made here, and is highly prized by experienced brewers.

THE daily product of petroleum in the Pennsylvania oil regions is 18,000 bbls.

THE STRAINS OF SHIPS AT SEA.

From "The Artizan."

A paper embodying an investigation of the strains which ships undergo at sea was read on February 9th, at the Royal Society, by Mr. E. J. Reed, C.B., late Chief Constructor of the Navy. The author, after pointing out that little or no practical progress had been made on this subject since the early part of the present century, proceeded to state that the introduction of steam navigation, and of iron and steel as shipbuilding materials, had rendered a thorough examination of it extremely necessary, and that he had consequently selected 4 ships, as types of the various descriptions of modern vessels —viz., Her Majesty's yacht Victoria and Albert, as a type of long, fine-lined, lightly-built ships, with great weight of engines and boilers in the middle; the Minotaur, as a type of long, fine-lined ships, with great weights distributed along their entire length; the Bellerophon, as a representative of short, stoutly built ships, with weights more concentrated; and the Audacious, as a model of ships with extremely concentrated weights. The smooth water strains of all these ships were illustrated by numerous diagrams embodying the results of various calculations, and the effects of placing such ships among waves were then no less fully investigated. The great bulk of the paper consisted of detailed calculations too long to insert, but some of the facts and figures deduced were very striking. It was shown, for example, that a ship like the Minotaur, floating among waves 400 ft. long and 25 ft. high from hollow to crest, which have a time of transit of about 8 ¾ sec., passed in half that time from a bending or breaking "moment" of 140,000 foot-tons tending to break her in two by the drooping of the ends to a reverse strain of 74,000 foot-tons, so that 15 times per minute a "wave of strain," as Mr. Reed designated it, having these enormous quantities for its positive and negative amounts, sweeps through the fabric of her hull. The Victoria and Albert yacht has to undergo, in like manner, strains which tend to break her downwards at the ends with a force of 16,400 foot-tons, and in less than 4 sec. encounters a strain tending to break her downwards at the middle, and let her engines and boilers fall through her, equal to nearly double this amount, or 31,000 foot-tons. It is remarkable that this change of strain in this lightly built hull is proportionately greater than that of either of the iron-clads. The Bellerophon's maximum strains in waves, similarly calculated, were 43,600 foot-tons and 48,800 foot-tons respectively. In illustrating the influence which rapid changes of strain exert upon structures, the author referred to the experiments of Sir W. Fairbairn, who has shown that the joints of an iron-riveted beam broke under the action of a rapidly alternating strain, although it was only ⅓ in amount of what the beam would sustain at rest. Mr. Reed stated that his investigations had shown many of the general principles laid down by former investigators, who had dealt with very different forms of ships, to be erroneous, and, in particular, opposed the very common notion that there is a compensating action between the strains of, and the wave actions exerted upon, very long fine-lined vessels. He further stated that while the weakness exhibited by many modern ships had induced him to enter upon these investigations, the result of them had been to convince him that calculations which had hitherto been neglected were becoming daily more and more necessary, especially as the length of steamships and the lightness of their construction in iron and steel were being very rapidly and simultaneously developed.

We hear that every steel rail manufactory in the country is now full with orders for the next 2 years, and that the price of the best Bessemer steel rail is some £12 per ton. The difficulty now appears to be not to pay for steel rails but to get them. This great demand for them arises from the marked economy in their use. Considerable savings are being made by our railway companies in the maintenance charges, due to steel rails. Thus experience has already supported theory as to the great advantage of steel rails.

STEAM ARTILLERY.

From "The Engineer."

Any proposition made by Mr. Bessemer, and published over his own signature in a public print, is certain to be read with attention by hundreds of men, who, like ourselves, admire his genius. In the present day, however, it is very well understood that no man is wise on all subjects, and we may add that this fact is especially true of Mr. Bessemer. We have perused with much care a long letter from his pen published in the "Times," which may be regarded as his latest contribution to mechanical science. It is to be regretted that the writer did not, before rushing into print, consult some competent engineer or mathematician as to the soundness of his views. Had he done so we fancy his own good sense would have stepped in to prevent him publishing a letter which is simply a tissue of absurdities. This is, no doubt, strong language, but we think that by the time our readers have heard what we have to say they will admit that no other words will accurately explain the character of the letter in question. It would be mere waste of space to reproduce Mr. Bessemer's letter in full. Its gist can be given in a very few words. Mr. Bessemer proposes the adoption of what we may term a steam mitrailleuse, as an adjunct to our national artillery; in other words, a steam Enfield rifle throwing a torrent of projectiles, mounted on a traction engine carrying a plentiful supply of bullets, and fitted with a mantlet to protect the gunner. There can be no doubt that such a weapon of offence and defence as Mr. Bessemer describes, if a possibility, would constitute a most valuable addition to the strength of any army; but unfortunately the thing as proposed by Mr. Bessemer is simply an impossibility, while his reasoning is from beginning to end based on the most erroneous notions, and betrays the greatest possible ignorance of certain mechanical truths, which we thought hitherto were well understood by the merest tyros in mechanical science.

Mr. Bessemer starts with the assumption that about 5 lbs. of coal and 3 gals. of water would exert force enough to raise 2,540 Enfield bullets to a height of one mile in a minute; which is probably true enough, though we have not checked his calculations, because it is unnecessary to do so. He assumes, furthermore, that a velocity of 1,900 ft. per second might be communicated to these 2,540 bullets by a current of steam, of 150 lbs. on the sq. in., flowing through a suitable tube. He admits, however, that it is possible the bullets might have a somewhat less velocity than that due to the rate of issue of steam of 150 lbs. on the sq. in., and modestly contents himself with 1,600 ft. per second, which is still, as he points out, considerably greater than that of a projectile fired from an Armstrong gun; and he finds a demonstration of the truth of his theory in the performance of a good steam fire engine. The details of his invention he prudently refrains from publishing, but he is quite ready to supply them, without fee or hope of reward, to the Government of this country.

There are two objections to Mr. Bessemer's scheme, which we shall consider separately. The first is that steam of 150 lbs. on the sq. in. could not possibly impart a velocity of anything approaching 1,900 ft. or even 1,600 ft. per second to an Enfield or any other bullet fired through a tube of practicable length. It will be admitted that what is true of an Enfield bullet in this matter must be true of any other projectile, larger or smaller. There can be no objection, then, to testing the accuracy of Mr. Bessemer's views by considering the case of a steam 32-pounder gun instead of an Enfield rifle, while there is the great advantage secured that we thereby eliminate fractions to a great extent—a matter of some importance in an article like this, written, not for mathematicians, but for every general reader who possesses some acquaintance with dynamics.

There is no principle more clearly laid down or better understood than this, that the effect produced on any given mass by a given force, bears a definite relation to the time of action of the force. In other words, a very small force acting for a long time may produce as much effect as a much greater force operating for a shorter time. We really owe an apology to our

readers for enunciating such a truism, but the statement is intended for Mr. Bessemer's benefit, which fact must be our excuse. Now let us see how it applies in the case of a steam gun. Let us suppose that we have a 32-pounder 21 ft. 4 in. long in the chase, and that the breech of this gun can be put into free communication by means of a short pipe 6.2 in. diameter, the same as the gun, with a gigantic steam boiler, in which is maintained a pressure of 150 lbs. to the sq. in.; we shall suppose that the ball fits steam tight but without any friction. The force brought to bear on it will then be $150 \times (6.2)^2 \times .7854 = 4{,}500$ lbs. in round numbers. Now if we suppose the ball to have a velocity of 1,600 ft. per second it will traverse the bore of the gun in the 75th part of a second. It is, therefore, evident that all the work which the steam can do upon it must be done in the 75th part of a second. We have then the following problem to solve: Given a weight of a little over 32 lbs., what force must be brought to bear on it during the 75th part of a second in order to impart a velocity of 1,600 ft. per second? If this force is greater than 4,500 lbs., then it is certain that our 32 lbs. ball cannot be driven from the gun with a velocity of 1,600 ft. per second by a force of 4,500 lbs. But if it cannot, Mr. Bessemer's reasoning must be erroneous. The required force can easily be ascertained by the well-known formula, $F\,t = m\,v$. Where F is the force, t the time of its action in seconds, m the mass of the body to be put in motion, an v the velocity. Let W = the weight of the ball, $32\frac{1}{6}$ lbs., $g = 32\frac{1}{6}$, F the required force, v the required velocity, m the mass of the ball, t the time of operation of the force. Then $m = \frac{32\frac{1}{6}}{32\frac{1}{6}} = \frac{W}{g} = 1$, and $F = \frac{m}{t}$ $v = 1 \times 75 \times 1600 = 120{,}000$ lbs. Therefore, it follows that a force—if the force acts but the $\frac{1}{75}$ part of a second—of not less than 120,000 lbs. must act on a weight of $32\frac{1}{6}$ lbs. in order to impart to it a velocity of 1,600 ft. per sec. But the force which Mr. Bessemer can bring to bear is but 4,500 lbs. Therefore Mr. Bessemer's reasoning is completely erroneous.

In another form it may be stated that a velocity of 1,600 ft. per sec. could not be imparted to a $32\frac{1}{6}$ lbs. shot, by the operation of a force of 4,500 lbs., in less than .0.3 of a sec.; but $1{,}600 \times .3 =$ 480 ft., which is the length of gun chase required. We fancy that Mr. Bessemer will hardly advocate the construction of a steam gun with a barrel 480 ft. long. It may be argued that, as the shot would not all at once acquire a velocity of 1,600 ft. per sec., the time during which the force would act would be prolonged, the bullet not passing through the whole length of the chase at 1,600 ft. per sec., but at some lower velocity, a mean between a speed infinitely small and 1,600 ft. per sec. Cheerfully granting this, Mr. Bessemer gains nothing. His gun barrel will, roughly speaking, admit of being cut down to a length of 240 ft., but if once we get beyond a length of chase of 20 ft. or so, it matters very little whether we stick on another 100 ft. or 100 yards. We need hardly stop to point out that all that we have said of a 32-pounder will apply with just as much force to an Enfield rifle bullet; the force and the weight may be estimated in ounces, or grains, or tons, but the numerical relations remain constant so long as the pressure of steam and the velocity remain unaltered. If a pressure of 150 lbs, on the sq. in. would suffice to impart a velocity of 1,600 ft. per sec., how is it, we may ask, that a pressure of 15 or 20 tons to the sq. in., due to the explosion of the powder charge, fails to impart a greater velocity than 1,200 ft. per sec., or thereabouts, to the projectiles fired from ordinary rifled guns?

We shall now consider the second objection to Mr. Bessemer's scheme. Let us suppose that the laws of nature are so far abrogated in his favor that a current of steam, moving at 1,900 ft. per sec., will really propel bullets at 1,600 ft. per sec. To do this he will admit that only 1 ball can be in the gun at the time. If a second is put in before the first is out the impelling force will be at once reduced in a way too obvious to need explanation. Therefore, the maximum number of balls which he could fire would be 75 per sec., and the quantity of steam used would be just one barrel full per bullet. It is evident, therefore, that the steam may be regarded as flowing from an orifice in the boiler at the rate of 1,900 ft. per sec., the orifice being of the same diameter as the bore of the gun. Let us suppose this, to use Mr. Bessemer's own figures, to be .6 sq. in., then the quantity of steam which the boiler must provide will be 13,680 cubic in. per

sec., 475 cubic ft. per min. 28,500 cubic ft. per hour. The volume of steam at 150 lbs. on the sq. in. is, water being unity, approximately 180, and $\frac{28,500}{180} = 158.3$ cubic ft. of water to be evaporated; in other words, Mr. Bessemer would have to provide a boiler of 160-horse power to maintain a constant current of steam of 150 lbs. pressure through a tube .6 of an inch in diameter. Such a boiler, we need hardly add, would weigh many tons, and would be quite out of place on the field of battle. Mr. Bessemer may, of course, get over the difficulty to some extent by reducing the number of bullets discharged in a given time, but even with this limitation it is evident that a boiler of great power must be provided if his steam gun is to prove even moderately efficient.

There are many other objections which can be brought against the scheme, but we shall not press them. The whole theory of the thing is defective from the very beginning, and is not only defective, but antiquated. Can it be possible that Mr. Bessemer never heard of Jacob Perkins' gun, which in a small way attained a certain amount of success with steam of 1,000 lbs. pressure on the sq. in.?

ON THE EFFICIENCY OF JET PROPELLERS.

By CAVALIERE E. BRIN, Director of Naval Construction, Ministry of Marine, Florence.

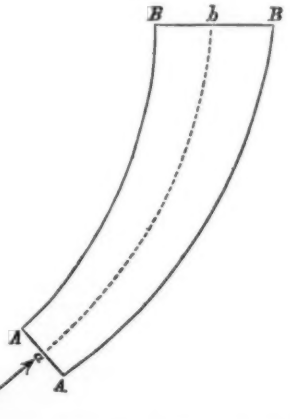
From "Journal of the Society of Arts."

1. Among the various plans for the propulsion of ships which have been proposed or tried, those in which the propelling force is produced by the reaction of one or more jets of water form a special category by themselves. Ruthven's hydraulic propeller applied first to the "Nautilus" and afterwards to the "Waterwitch, belongs to this class. The results obtained with it, so far as the amount of useful effect is concerned, were much more satisfactory in the latter vessel than in the former, but were nevertheless, very inferior to those given by the screw or paddle-wheel. Hydraulic propellers, in certain respects, offer some advantages, and might, under certain given circumstances, be preferred to any other. It has, consequently, seemed to me that it might not be altogether useless to investigate the theory of these propellers, with a view to ascertain if the low amount of useful effect obtained ought to be altogether attributed to the inherent defects of the system, or if it might not be remedied by the adoption of suitable arrangements.

2. In hydraulic propellers, the force of propulsion, that is to say, the thrust necessary to cause the ship to advance, is obtained, as I have already remarked, by the reaction of one or more horizontal jets of water, in a fore and aft direction; in other words, the propelling force is due to the action of a mass of water in motion upon the bounding surfaces of the vessel in which it moves.

Let A A, B B, be a receptacle in which a mass of liquid is in motion, and let A A be the inlet section of the liquid and B B that of its exit. Let it be supposed, too,

Fig. 1.



that the arrangements are such that we may assume all the small streams of water to have velocities which are equal and parallel both at their entrance and exit, and normal to the sections A A and B B; also that the motion has become uniform.

Let Ω_0 be the area of the section A A.
Ω_1 that of B B.
V_0 the velocity of the liquid at A A.
V_1 its velocity at B B.
P_0 P_1 the pressures on the extreme sections of the liquid at A A and B B.

α_0, β_0, γ_0, the angles which a normal to the section A A would make with the three orthogonal axes, x, y, z, the last being the vertical one.

α_1, β_1, γ_1, corresponding angles for the section B B.

X, the force impressed on the containing vessel in a horizontal direction, and parallel to x.

Y, the corresponding force impressed in a direction parallel to y.

Z, the vertical force impressed on the vessel —that is in a direction parallel to z.

π, the weight of the liquid contained in the receptacle A A, B B.

Q, the weight of a unit of volume of this liquid.

And g, the velocity impressed by gravity on heavy bodies in a unit of time.

By hydrodynamics, we have for the values of X, Y, Z:—

$$(1.)\ X = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos\alpha_1}{\Omega_1} - \frac{\cos\alpha_0}{\Omega_0}\right)$$

$$(2.)\ Y = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos\beta_1}{\Omega_1} - \frac{\cos\beta_0}{\beta_0}\right)$$

$$(3.)\ Z = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos.\ V_1}{\Omega_1} - \frac{\cos V_0}{\Omega_0}\right)$$

If the vessel A A, B B, have a rectilinear and uniform motion, and this is the case of the propellers of ships, the values of X, Y and Z remain constant.

3. If the inlet section of the vessel, A A, be immersed in the liquid, P_0 is the pressure of the exterior liquid on the plane, A A. Now, as it is required to find the force impressed on the vessel in directions parallel to the three axes, x, y, and z, we may observe that the pressures exerted by the liquid on the exterior immersed portion of the vessel are zero in a horizontal direction, and that no account must therefore be taken of the components $P_0 \cos \alpha_0$ and $P_0 \cos \beta_0$ in the values of X and Y, given by the equations (1) and (2).

With regard to the pressure P_1 on the section B B, this cannot be exerted without causing an equal and directly opposite pressure, either on the sides of the vessel or on the fastenings (in our case on the ship) to which it is fixed. Suppose, for instance, that this pressure is caused by a plunger, the rod of which is merely a prolongation of the piston-rod of a steam cylinder, then on the end of this cylinder there will be produced a pressure, P_1 equal and directly opposite to the pressure, P_1, exerted on the section B B of the liquid. Thus the pressure, P_1, will have no influence upon the horizontal thrusts exerted upon the system to which the vessel is fixed. Therefore, so far as concerns the horizontal thrusts produced by a mass of liquid in motion on the sides of a containing vessel, considered as propelling forces of the material system, of which this containing vessel forms a part, their value will be expressed by—

$$(4.)\ X = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos\alpha_1}{\Omega_1} - \frac{\cos\alpha_0}{\Omega_0}\right)$$

$$(5.)\ Y = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos\beta_1}{\Omega_1} - \frac{\cos\beta_0}{\Omega_0}\right)$$

4. This premised, let us consider an hydraulic propeller of the kind proposed by Mr. Ruthven. In this system, an hydraulic wheel or turbine, with its axis vertical, sucks in water from the sea through holes in the bottom of the ship, and this water is discharged through two horizontal pipes fixed on each side of the ship at the height of the load water-line. The openings in the bottom are so arranged that the water enters the ship from forward to aft, and in a horizontal direction.

We have thus a mass of water in motion in a vessel fixed in the ship, and the pressure, parallel to the direction of motion of the ship, sustained by the bounding surfaces of this vessel, will be the thrust that caused the propulsion.

If we take for the axis of x a horizontal line parallel to the middle line plane of the ship, and if we take for the positive direction that from the origin of coordinates to the bow of the ship, the amount of this thrust will be given by equation (4), in which Ω_0 and Ω_1 will be the areas of the orifices of supply and discharge, and V_0 and V_1 the velocities of the water as it passes these orifices; we shall have in this case—

$$\alpha_0 = 180_0,\ \cos\alpha_0 = -1;\ \alpha_1 = 180_0,\ \cos\alpha_1 = -1.$$

We shall therefore have—

$$(6)\ X_1 = \frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{1}{\Omega_1} - \frac{1}{\Omega_0}\right);$$

And as the volume of water which enters the ship must be equal to that which leaves it, we shall have—

$$\Omega_1\,V_1 = \Omega_0\,V_0 \text{ and}$$

$$(7.)\ X_{_} = \frac{Q}{g}\,\Omega_0 V_0 (V_1 - V_0)$$

Calling M the unit of water discharged during a unit of time, we have—

$$(8.)\ X_1 = \frac{Q\,M}{g}\,(V_1 - V_0).$$

Let us call U the speed of the ship. The outside water is at rest, and on entering the ship is met by the water at the inlet section with a relative velocity of $U-V_0$.

At the inlet section, besides the pressure due to the hydrostatic head at this depth, there is a further pressure corresponding to that necessary to impress in a unit of time a velocity $U-V_0$ on a mass $\frac{Q\,M}{g}$. This pressure can be expressed by

$$\frac{Q\,M}{g}\,(U-V_0);$$

it is horizontal, and its direction is from forward to aft.

The final thrust sustained by the ship, and generated by the volume of water, M, which enters it in a unit of time and leaves it by the discharge pipes, that is to say, the force of propulsion, F, will therefore have for value:

$$F=\frac{A\,M}{g}\left\{V_1-V_0-(U-V_0)\right\}\text{ or}$$

$$(9.)\quad F=\frac{A\,M}{g}\,(V_1-U).$$

Calling R the resistance offered by the ship to its progress through the water, we have F = R, and the work necessary to overcome the resistance, or the useful work in a unit of time, will be—

$$(10.)\quad R\,U=\frac{A\,M}{g}\,(V_1-U)\,U.$$

5. Let us now seek to ascertain what will be the amount of work necessary to obtain this propelling force, F, and this useful work, R U.

We will retain the notation of section 4 with the following additions:

L_m, the work developed during a unit of time to produce the jets of water which serve to propel the ship.

V_a, the absolute velocity with which the water leaves the ship; we shall have $V_a = V_1 - U$.

h, the height of the orifices of discharge above the water section of the ship.

During a unit of time, a mass of outer water, $\frac{Q\,M}{g}$, which was at rest, enters the ship and leaves it with an absolute velocity, V_a, at a height, h, above its original level. There will thus be a *vis viva* acquired of $\frac{Q\,M}{g}V_a^2$, and a work expended of $Q\,M\,h$.

On this mass of water there acts the force of reaction of the sides of the vessel, along the length of which this mass of water moves, a force of reaction whose value as found above, is $\frac{Q\,M}{g}\,(V_1-U)\,U$. The work exerted during a unit of time to put this mass of water in motion, that is to say, the work of resistance, will therefore be:—

$$Q\,M\,h+\frac{Q\,M}{g}\,(V_1-U)\,U.$$

During the same period of time there has been transferred to this mass of water in motion a motive work, L_m.

If we neglect friction, the motive work, conformably with the principle of the conservation of *vis viva*, must be equal to the work of resistance

$$Q\,M\,h+\frac{Q\,M}{g}\,(V_1-U)\,U,$$

plus half the *vis viva* acquired, *plus* half the loss of *vis viva* occasioned by the shock given to the water on its entrance into the ship. During a unit of time, in consequence of this shock, a mass of water $\frac{Q\,M}{g}$ changes its velocity suddenly from U to V_0; the velocity lost in this shock is therefore $U-V_0$, and the loss of *vis viva* is $\frac{Q\,M}{g}\,(U-V_0)^2$. The principle of the conservation of the *vis viva* next gives us the following equation :—

$$L_m=Q\,M\,h+\frac{Q\,M}{g}\,(V_1-U)\,U+\frac{Q\,M}{g}\,\frac{V_a^2}{2}+\frac{Q\,M}{g}\,\frac{(U-V_0)^2}{2}.$$

But by equation (9) we know that

$$\frac{Q\,M}{g}\,(V_1-U)=F=R.$$

We therefore have—

$$(11.)\quad L_m=R\,U+Q\,M\,h+\frac{Q\,M}{g}\,\frac{V_a}{2}+\frac{Q\,M}{g}\,\frac{(U-V_0)}{2}$$

The first term of the second member of this equation represents the work necessary to overcome the resistance of the ship, or the useful work. It therefore follows that the actual work expended in this hydraulic propeller must be equal to the useful work, *plus* the work necessary to raise the amount of water employed to the height of the discharge pipes above the water-line, *plus* one-half of the *vis viva* acquired by the water

when it leaves the ship, *plus* one-half of the loss of *vis viva* arising from the shock encountered by the water on its entrance into the ship.

We might, therefore, have written down this equation at once from *a priori* considerations. The first term of the second member of this equation representing, as we have said, the useful work, all the other terms represent losses of work.

It will then be necessary so to arrange matters as to make these terms zero, or else to render them as small as possible.

The term $Q\,M\,h$ will be zero when $h = 0$, which shows us that it is of advantage to place the discharge pipes at the load water line or below it.

The term $\frac{Q\,M}{g}\frac{(U-V_0)^2}{2}$ will be zero when $U=V_0$; while the term $\frac{Q\,M}{g}\frac{V_a^2}{2}$ will be zero when $V_a = 0$; that is, if the water left the ship without any velocity at all. But we must observe that $R = \frac{Q\,M}{g}V_a$, so that it is impossible to make $V_a=0$, since in this case we should require an infinite amount of water, and inlets and outlets of infinite size. Take $V_a = a\,U$, and suppose that the conditions pointed out above for rendering the other losses of work zero have been satisfied, we shall have

$$L\,m = R\,U + \frac{Q\,m}{g}\,a\,\frac{^2U^2}{2}$$

and

$$R = \frac{A\,M}{g}\,a\,U;$$

whence we obtain

$$L\,m = R\,U\left(1+\frac{a}{2}\right)$$

and the coefficient of useful effect of the motive work will be

$$U_t = \frac{R\,U}{a\,U} = \frac{2}{2+a}$$

If $a = 1$ (as in the "Waterwitch") we shall have $U_t = 0.66$.

6. If the openings by which the water enters the ship, instead of being arranged as in the "Waterwitch," were so contrived that the water came into the ship in a direction contained in a plane perpendicular to the middle line plane of the ship, the outside water, in that case, which is at rest when it enters the ship, would receive a shock with the velocity, U, of the ship; it would therefore produce an increase of resistance, of which the value would be $\frac{Q\,M}{g}U$, and there would be a loss of *vis viva* equal to $\frac{Q\,M}{g}\frac{V^2}{2}$.

The value of the horizontal thrust produced by the water in motion would be given by the equation (4) on making

$a_0 = 90°$, $\cos a_0 = 0$; and $a^1 = 180°$, $\cos a_1 = -1$.

We should, therefore, have—

$$X = \frac{Q\,M}{g}V_1.$$

This thrust ought to be equal to the resistance of the ship *plus* the increase of resistance indicated above. We shall then have—

$$\frac{Q\,M}{g}V_1 = R + \frac{Q\,M}{g}U;$$

whence we get

$$R = \frac{Q\,M}{g}(V_1 - U)$$
$$= \frac{Q\,M}{g_a}V_a$$

The resisting work overcome, that is to say, the useful work will be—

$$R\,U = \frac{Q\,M}{g}U\,(V_1 - U),$$
$$= \frac{Q\,M}{g}U\,V_a.$$

The principle of conservation of *vis viva*, by considerations similar to those set forth in section 5, leads us directly to the following equation—

$$L\,m = R\,U + Q\,M\,h + \frac{Q\,M}{g}\frac{V_a^2}{2} + \frac{Q\,M}{g}\frac{U_2}{2}$$

We shall see immediately that we ought to make $h = 0$.

If we take $V_a = a\,U$, we shall have—

$$L\,m = R\,U + \frac{Q\,M}{g}\frac{a^2\,U^2}{2} + \frac{Q\,M}{g}\frac{U_2}{2}$$

We have—

$$R = \frac{Q\,M}{g}V_a$$

which gives

$$L\,m = R\,U\left(1+\frac{a}{2}+\frac{1}{2\,a}\right)$$

and the coefficient of useful effect of the motive work will be—

$$U_t = \frac{1}{1+\frac{a}{2}+\frac{1}{2\,a}}$$

If $a = 1$
$U_t = 0.50$

We see, therefore, that this arrange-

ment is less advantageous than the preceding. Such an arrangement was adopted in a steamboat constructed by Cockerill's Company, which was exhibited at the Paris Exhibition of 1867.

7. Let us suppose, now, that the openings in the bottom of the ship are arranged in such a manner that the water enters in a direction horizontal and parallel to the middle line plane, and from aft forward.

In this case, the thrust exerted by the body of water in motion will be given by equation (4) on making

$$a_0 = 0,\ \cos a_0 = 1;\ a_1 = 180^\circ,\ \cos a_1 = -1.$$

We shall then have—

$$(12.)\ X = \frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{1}{\Omega_1}+\frac{1}{\Omega_0}\right) = \frac{Q\,M}{g}(V_1 - V_0).$$

This value of X represents the force of propulsion F, and we shall have—

$$(13.)\ F = R = \frac{Q\,M}{g}(V_1 + V_0)$$

8. With regard to the work required in order to obtain this force of propulsion, it may be determined by considerations similar to those set forth in section 5.

We will use the same rotation as that adopted in the preceding sections.

In a unit of time—

The *vis viva* acquired will be $\frac{Q\,M}{g}V_a^2$.

The motive work developed, L_m.

The work of resistance due to gravity, $Q\,M\,h$.

The work of resistance due to the reaction of the surface of the channels along which the water moves,

$$X\,U = \frac{Q\,M}{g}(V_1 + V_0)\,U.$$

We shall therefore have

$$(14.)\ L_m = \frac{Q\,M}{g}\frac{V_1^2}{2} + Q\,M\,h + \frac{Q\,M}{g}(V - V_0)U.$$

or as

$$R = \frac{Q\,M}{g}(V_1 - V_0).$$

$$(15.)\ L_m = R\,U + Q\,M\,h + \frac{Q\,M}{g}\frac{V_a^2}{2}.$$

The first term of the second member of this equation represents the useful work; all the others injurious work.

We must therefore make—

$$h = 0$$
$$V_a = 0$$

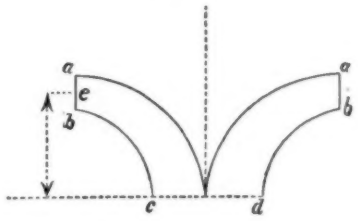
Having satisfied these conditions, we shall have

$$L_m = R\,U,$$

and the coefficient of useful effect, $U_t = 1$. That is to say, the motive work will equal the work of resistance. This propeller should, therefore, be theoretically perfect.

9. It is now necessary to determine what conditions must be satisfied by the hydraulic machine which has to set the water in motion and discharge it from the ship, so as to utilize the motive power as perfectly as possible. For this purpose we may employ one of the numerous hydraulic machines for raising water. But as it is required to produce continuous jets, and to avoid intermission, as well as to set in motion very considerable bodies of water, there can be no doubt that centrifugal pumps or turbines constitute in this case the best form of hydraulic machine to employ.

FIG. 2.



Let us call

- T, the moving force transmitted to the shaft of the turbine in a unit of time.
- V, the velocity of the extremities of the vanes of the turbine (if u is the angular velocity).
- R, the radius of the turbine.
- N, the number of revolutions of the turbine in a unit of time: so that $V = R\,u = \frac{2\,\pi\,N\,R}{60}$.
- H, the height of the centre, e, of the extremities of the vanes above the section, $c\,d$, of the inlet of water into the turbine.
- H_1, the height of the orifices of discharge above the point e.
- P, the height of the column of water which measures the pressure at the section, $c\,d$, of the inlet of the water into the turbine.
- v, the velocity of the water at the section $c\,d$.

For the remainder we will adhere to the notation of the preceding sections.

If we disregard the friction and the loss of work due to throttling, sharp turns,

and so forth, the work, T, ought to be equal to that necessary to raise the weight Q M to the height $H + H_1 - P$, *plus* the work corresponding to one half the *vis viva*

$$\frac{Q\,M}{g}(V_1^2 - v^2)$$

acquired by the water, from its entrance into the turbine until it leaves the orifices of discharge, *plus* also the work corresponding to one-half the losses of *vis viva* that take place in this kind of hydraulic machine, and which are:—

$\frac{Q\,M}{g}a^2$, on the entrance of the water into the turbine, where a is the velocity lost in the entering.

$\frac{Q\,M}{g}b^2$, on the exit of the water from the turbine, where h is the absolute velocity with which it leaves the turbine.

We shall therefore have

$$(16.)\quad T = Q\,M\,(H + H_1 - P) + \frac{Q\,M}{g}\frac{V_1^2}{2} - \frac{Q\,M}{g}\frac{v^2}{2} + \frac{Q\,M}{g}\frac{a^2}{2} + \frac{Q\,N}{g}\frac{b^2}{2}.$$

The loss of *vis viva* $\frac{Q\,M}{g}\frac{a^2}{2}$ on the entrance of the water into the turbine, may be almost entirely obviated by making the vanes of a suitable shape; we shall therefore neglect it.

Let us put

$$(17.)\quad H + H_1 - P + \frac{V_1^2}{2g} - \frac{v^2}{2g} = \frac{\mu^2}{2g}.$$

$\frac{\mu^2}{2g}$ will represent the column of water which the turbine has to take up, and $Q\,M\,\frac{\mu^2}{2g}$ the useful work in a unit of time.

We shall have

$$(18.)\quad T = Q\,M\,\frac{\mu^2}{2g} + \frac{Q\,M}{g}\frac{b^2}{2}.$$

The term $\frac{Q\,M}{g}\frac{b^2}{2}$ represents a loss of work; we ought, therefore, to diminish this term or the velocity, b, as much as possible.

Let us determine this velocity.

The relative motion of the water in the turbine is determined by the pressures at the inlet section, $c\,d$, and by those at the outlet, $a\,b$, by gravity and by the centrifugal force.

Let v_1 be the relative velocity acquired by the water on its exit from the turbine under the action of these forces. The work developed by these forces in a unit of time will be—

1st. That of the pressure at the entrance will be $Q\,P\,\omega\,U$, ω being the area of the section through which the water enters the turbine, and U the relative velocity of the water at this section.

Now we have $\omega\,U = M$, so that the work done by this force will be $Q\,P\,M$.

2d. That of the pressure upon the orifices of discharge of the water from the vanes of the turbine will be $Q\,P_1\,M$.

3d. The work done by gravity will be $Q\,M\,h$.

4th. With regard to the work done by the centrifugal force, we know that the work transmitted by this force to a body $\frac{Q\,M}{g}$ which, having a rotary motion of which the angular velocity is ω, starting from rest, moves off from the axis to a distance, R, has for its expression

$$\frac{Q\,M}{g}\frac{\omega^2\,R^2}{2} = \frac{Q\,M}{g}\frac{V^2}{2}.$$

The principle of the conservation of *vis viva* then leads to the following equation:—

$$Q\,P\,M - Q\,P_1\,M - Q\,M - + \frac{Q\,M}{g}\frac{V^2}{2} = \frac{Q\,M}{g}\frac{v_r^2}{2}$$

whence we have

$$P - P_1 - H + \frac{V^2}{2g} = \frac{v_r^2}{2g}.$$

The velocity V_1 of the water at the orifices of discharge will be due to the height $P_1 - H_1$. We shall therefore have

$$\frac{V_1^2}{2g} = P_1 - H_1 \text{ and } P_1 = \frac{V_1^2}{2g} + H_1$$

which gives us

$$\frac{v_r^2}{2g} = P - \frac{V_1^2}{2g} - H_1 - H + \frac{V^2}{2g}$$

that is to say

$$\frac{v_r^2}{2g} = \frac{V^2}{2g} - \frac{\mu^2}{2g}$$

Whence we derive

$$v' = \sqrt{V^2 - \mu^2}$$

The velocity of the water, v, which it will have when it quits the turbine, will be the resultant of V, the velocity of the ends of the vanes, and of the relative velocity v_r of the water tangentially to the ends of the vanes.

Calling e the angle which the tangent to the ends of the vanes makes with the outer circumference of the turbine, we shall have—

$$(19)\quad v^2 = v_r^2 \sin^2 e + (V - v_r \cos e)^2.$$

We have seen that it is necessary to endeavor to render v a minimum; with this object we must make $e = 0$.

We shall then have

$$b^2 = (V - v_r)^2 - (V - \sqrt{V^2 - \mu^2})^2$$

In order to get rid of the velocity v, it would be necessary to have $V = \infty$, whence we see that it is impossible to overcome the loss of momentum $\frac{Q\,M}{g} v^2_1$ and that it is an advantage to make the turbine revolve with a great velocity.

If we substitute the value of v^2 found above in the equation, which gives us the expression of the motive work, we shall obtain the following equation:

$$(20.)\quad T = Q\,M\,\frac{\mu^2}{2g} + Q\,M\,\frac{(V - \sqrt{V^2 - \mu^2})^2}{2g}$$

The term $Q\,M\,\frac{\mu^2}{2g}$ represents, as we have said, the useful work obtained by the turbine, so that the coefficient of useful effect of the motive work will be—

$$U_t' = \frac{\mu^2}{\mu^2 + (V - \sqrt{V^2 - \mu^2})^2}$$

This coefficient can only become unity when $V = \infty$.

If we make $V = \mu$, we shall have $U_t' = 0.50$.
" $V = 1.25\,\mu_1$ " $U_t' = 0.80$.
" $V = 2\,\mu$ " $U_t' = 0.93$.

But practically we cannot make the angle e vanish, that is to say we cannot arrange the ends of the vanes tangentially to the outer circumference of the turbine, for if we did so the water which leaves one vane would strike the following.

We cannot make $e = 20°$ as in good centrifugal pumps; then we shall have—

$$v^2 = v_r^2 \sin^2 20° + (V - v_r \cos 20°)^2.$$

In this case the coefficient of useful effect will have for value—

$$(21.)\quad U_t' = \frac{\mu^2}{\mu^2 + (V^2 - \mu^2)0.12 + (V - V\sqrt{V^2 - \mu^2} + 0.94)^2}$$

If we make $V = 2\,\mu$, we shall have $U_t' = 0.71$.

This theoretical coefficient of useful effect cannot be practically attained. It is impossible to make the term $\frac{Q\,M}{g}\,\frac{a^2}{2}$ zero in relation to the entrance of the water into the turbine. It is also necessary to take account of all the losses of *vis viva* arising from throttling angles and friction during the passage of the water, from its entrance into the ship to its exit.

Having regard to these different causes of loss of worth, the practical coefficient of useful effect, U''_t, will be some fraction of the theoretical one.

We shall therefore have

$$U''_t = A\,U'_t,$$

A being a constant coefficient, the mean value of which, judging from what is generally the case in hydraulic machines, may be taken at 0 85.

10. In order to obtain the final coefficient of useful effect of this propeller, it will be necessary to multiply U_t, of which we have spoken in sections 5, 6 and 7, by the coefficient of useful effect belonging to the hydraulic machine, so that this final coefficient of useful effect will be

$$U'''_t = U_t \times U''_t = U_t \times A\,U''_t.$$

In each particular case we shall adopt for these values of U_t and U'_t those found above.

If we adopt the arrangements referred to in section 5, which are those of the "Waterwich," and if the velocity of discharge V_1 of the water be double that of the ship, we shall have $U_t = 0.66$, and if for the turbine we make such arrangements as to have the maximum effect, and if we have $V = 2\,\mu$, we shall have a final coefficient. $U''_t = 0.66 \times 0.85 \times 0.81 = 0.45$, which is a very low useful efect, and inferior to that obtained with the screw and the paddle-wheel.

With the arrangement referred to in section 6, this coefficient would be lower still.

The most favorable arrangement is that referred to in section 7. We can in this case obtain a useful effect $U_t = 1$, and a final useful effect (with $V = 2\,\mu$),

$$U''_t = 1 \times 0.85 \times 0.71 = 0.60.$$

This coefficient of useful effect is about the same as those realized by the screw-propeller and the paddle wheel.

11. Recapitulating, we arrive at the following conclusions:

In order that an hydraulic propeller may act under good conditions, it is necessary to arrange things so as to insure:

a. 1st. That the water shall enter the ship in a horizontal direction, and parallel to the middle line plane, and from aft to forward.

2d. That the orifices of discharge shall be situated either at the level of the load water line or below it.

3d. That the water shall leave the orifices of discharge in a horizontal direction and parallel to the middle line plane of the ship, and shall have a relative velocity equal to that of the ship, that is to say, an absolute velocity equal to zero.

b. With regard to the hydraulic machine employed to draw the water from the sea and discharge it from the ship, that, if we make use of a turbine, the vanes shall have to be curved in such a manner that the water shall enter the turbine without shock, and that the ends of the vanes shall make a very acute angle (about 20°) with the outer circumference of the turbine.

It is necessary, also, that the turbine shall revolve rapidly, so as to have a very high velocity at its outer circumference.

These conditions being satisfied, we can obtain with hydraulic propellers a mean coefficient of 0.60.

12. The "Waterwitch" has been fitted with an hydraulic propeller, of which we know the results.

We will proceed to examine if these accord with the theory set forth in the preceding sections.

In the "Waterwitch," we have:—*

Area of the orifices of discharge—

$$\Omega_1 = 6 \text{ sq. ft.} = \overset{m}{0}.5538.$$

Velocity of discharge of the water—

$$V_1 = 30 \text{ ft.} = \overset{m}{9}.135.$$

Volume of water discharged in a second—

$$M = 5059 \text{ litres.}$$

Area of immersed midship section—

$$B^2 = \overset{m}{3}1.85.$$

Speed of ship.

$$U = 15 \text{ ft.} = \overset{m}{4}.57 = \frac{V_1}{2}.$$

$$V_a = V_1 - U = U = 4.57.$$

Area of the openings admitting the water into the ship—

$$\Omega_0 = 30 \text{ sq. ft.} = \overset{m}{2}.769.$$

* These data are taken from newspaper articles and engravings, and are perhaps not altogether exact. With more correct data we should be able to correct the calculations.

Velocity of the water on its entrance into the ship—

$$V_0 = \frac{V_1}{5} = \frac{2\,U}{5}.$$

In the "Waterwitch," the openings by which the water is admitted into the ship open forward, and the water enters them horizontally.

This is the case considered in section 4; and we therefore have $R = \frac{Q\,M}{g}(V_1 - U)$, which gives us for the "Waterwitch," R = 2,402 kilogrammes.*

The work required to propel the "Waterwitch," (independently of the losses of work due to the hydraulic machine itself), will be given by equation (11) of section 5. We shall therefore have

$$L_m = R\,U + Q\,M\,h + \frac{Q\,M}{g}\frac{V_a^2}{2} + \frac{Q\,M}{g}\frac{(V - V_0)^2}{2}$$

For the "Waterwitch," we have

$$h = 0;\ V_a = U;\ V_0 = \frac{2}{5}\,U,$$

and as

$$R = \frac{Q\,M}{g}(V_1 - U)$$

$$= \frac{Q\,M}{g}\,U.$$

From which we get

$$\frac{Q\,M}{g} = \frac{R}{U}.$$

On substituting this value of $\frac{Q\,M}{g}$ in the above equation, we shall have

$$L_m = R\,U\,(1 + \tfrac{1}{2} + \tfrac{2}{25})$$

we shall have

$$= R\,U \times 1.76.$$

The coefficient of useful effect would therefore be $U_t = 1.57$.

We see that the greater portion of the loss of work arises from the too great velocity of the water when it quits the ship. The above coefficient is still further reduced by the losses of work due to the hydraulic machine or turbine.

In the "Waterwitch" the vanes of the turbine, instead of being curved and ar-

* Assuming that the resistance of ships is proportional to the immersed surface of the midship section, and to the square of the velocity, we shall have $R = K\,B^2 V_2$, where K is a constant. If we make R = 2,402 kilogrammes for the "Waterwitch," we find that K = 361. This value of K agrees with the admitted value of this coefficient in ships of the size and fineness of lines of the "Waterwitch" which shows the correctness of our theory. It may be observed that, with this system of propulsion, it is very easy to determine the resistance of ships without having recourse to dynamometers.

ranged so that the water shall quit them in a direction almost opposite to that of the rotation of their extremities, that is to say, with a very low absolute velocity, have their ends normal to the outer circumference of the turbine.

Under these conditions, the absolute velocity (b) with which the water quits the turbine will be given by equation (19) when we make $e = 90°$. We shall then have

$$b_2 = v_r^2 + V^2$$

and as

$$v_r = \sqrt{V^2 - \mu_2}$$

we shall have

$$b^2 = 2V^2 - \mu^2.$$

This value of b^2 being substituted in the equation (18) we shall have

$$T = \frac{Q\,M}{2g}\,2V^2.$$

The useful work is $Q\,M\,\frac{\mu_2}{2g}$ as we have observed in section 9.

The theoretical coefficient of useful effect for this turbine will therefore be

$$U'_t = \frac{\mu^2}{2V^2}.$$

In the "Waterwitch," we have:—

D, the diameter of the turbine $= 4.27\,m.$

Number of revolutions per minute, N $= 42.$

We have, therefore $V = 9.50\,m.$

The area of the sections of discharge through which the water quits the turbine is about 80 sq. ft. We have, therefore, $V_r = 0.68\,m.$, and as we have $V_r^2 = V^2 - \mu^2$, we get $\mu^2 = 90$. We have therefore—

$$U'_t = \frac{\mu^2}{2V^2} = \frac{90}{2\,(9.50)^2} = 0.50.$$

The final coefficient of useful effect in the "Waterwitch" would therefore be—

$$U''_t = U_t \times A\,U'_t = 0.57 \times 0.85 \times 0.50 = 0.24,$$

a very low coefficient, and one which must be attributed to the arrangements adopted for their propeller itself, with which we have a useful effect of 0.57, and for the hydraulic machine, with which we have a useful effect of 0.50.

These theoretical results agree with those realized in practice.

In the trials of the "Waterwitch" in which the above results have been obtained, an indicated horse power of 828 was realized.

The resistance, R, of the "Waterwitch" being 2,402 kilogrammes, and the speed 4.57 $m.$ per second, the work developed by this resistance in horses of 75 kilogrammètres is 147.

The coefficient of useful effect will therefore be $\frac{147}{828} = 0.18$. By assuming the value 0.24, found above as the coefficient of useful effect of the propeller, we should have as the coefficient of useful effect of the engines $\frac{0.18}{0.24} = 0.75$, which is a probable coefficient for a marine steam engine.

The results obtained in practice agree therefore with those deduced from theory.

13. Let us now endeavor to ascertain what results might be arrived at in the "Waterwitch," by fitting this ship with a hydraulic propeller arranged as pointed out by theory.

The openings by which the water enters should be turned towards the stern of the ship; and we ought to have $V_0 = V_1 - U = O$; that is, $V_1 = U = 4.57$.

We have

$$R = \frac{Q\,M}{g}\,(V_0 + U_1)$$

$$= \frac{Q\,M}{g} V_1 \left(\frac{2}{5} + 1\right).$$

And

R = 2,402 kilogrammes.

We shall find from this, that the amount of water to be discharged in a second, M, should be equal to 3,500 litres.

The area of the orifices of discharge must then be

$$\Omega_1 = \frac{3500}{4.57} = 0.76^{m}.$$

With such arrangements we should have, as seen in section 5, a coefficient of useful effect of the propeller equal to unity.

With regard to the hydraulic machine itself, by arranging it as explained in section 9, we are able to realize a coefficient of useful effect $U_1 = 0.71$, so that we should have a final coefficient of useful effect of $0.85 \times 0.71 = 0.60$, instead of 0.24, as in the "Waterwitch" with her present arrangements, that is a useful effect exceeding that obtained in the "Waterwitch" in a ratio of 2.50 to 1.

Instead of having 828 horses' power indicated by the engines, it would be sufficient to realize 331. As we have already seen, this advantage may be obtained by

making the area of the section of the orifice of discharge 0.55 instead of 0.76. But the quantity of water to pass through would be less, that is to say, 3,500 litres per second, instead of 5,000; so that by using a higher velocity the turbine might be made smaller, and the machinery lighter.

SMALL-GAUGE RAILROADS.*

By ALFRED F. SEARS, C. E.

The utter isolation of regions not possessing the advantages of the railroad, which are accounted essential to a wholesome civilization, has led to many devices among engineers by which the use of this instrument of modern progress may be made more accessible to poor and remote communities.

In this country, as in England and some of the Continental kingdoms, the railroad is becoming the common highway of the people; so that, to live off a line of railroad is no longer to be in the living world, but buried in an out-of-the-way place.

In the countries of Northern Europe—in Norway, Sweden and Russia—where a few lines exist, but no complete systems, the Governments have turned their attention to the business and appointed boards of commissioners who have investigated the railroads of the world, to report the cheapest and make such suggestions for reducing their cost as shall place the possession of extended systems within reach of their respective Governments; and in accordance with the same general demand, American engineers have been invited to India because they build cheap railroads.

The problem is reaching, indeed has reached, a happy solution in the adoption of lines of very much narrower gauges, steeper gradients and sharper curves. Lines on which the cars and engines are all smaller and lighter than has been common.

These systems have ceased to be experimental; on the contrary, so successful have they been, that even in the United States, where railroads are built the cheapest, the public attention is being drawn to them, and prudent men are asking why every section may not have its railroad when they can be provided at such cheap rates?

I have long been impressed with the opinion that we are spending more money in the first cost of railroads than is necessary; and accordingly, in my estimates for the construction of this road, I have reduced the width of the road-bed and introduced temporary expedients, to save building with borrowed money, so that I have been able to cut down the cost of the work, below the average of railroads in this section, more than $3,000 per mile.

I apprehend that but few persons state the correct problem to themselves when they proceed to build a railroad. They ask, *How much money can be commanded* for the work? Whereas they should rather ascertain, *What is the least amount* for which an object can be properly attained?

The common statement of the question thus corrected in our case would probably be, What is the least sum for which a railroad can be built between our termini?

We have given, a certain amount of terminal business to be moved along or across the country, and a certain section to be accommodated with as good means of transportation from point to point as the highest requirements of the best condition of a farming community demand. What is the cheapest method by which this duty can be properly accomplished?

Such method of transportation will, of course, be a railroad on which the traffic is done with steam. But, is it essential that we build such a road as the New York Central or the Erie? Shall we build the ordinary railroad with the ordinary cars, simply because we have become accustomed to them, without considering the necessities of the case? If the experience with such a road proves it to be the cheapest and as remunerative as we have any right to expect from the transaction of the business in hand, then it is undoubtedly the best thing to be

* Extracts from a report to the Board of Directors of the Pennsylvania and Sodus Bay Railroad Company.

done. If it is the best to be had without resorting to experiment, then we should adopt it.

But, under existing circumstances, seeing that the railroad has been so improved in the last few years as to insure positive and large dividends at lower rates of charge for transportation, there seems to be good reason why we should examine the new methods and ascertain if they contain anything of practical value to us.

In this paper I propose to show,

First.—Some reasons why railroads, although paying dividends, for they generally do, are not as remunerative at cheap rates as they should be ; and why, also, they are not as valuable property to the unspeculating investor as they may be.

Second.—The changes in the system by which they have been made a safe investment, and placed within the reach of every fairly settled section of country.

Third.—The application of the system to our uses and the cost of its construction, with some estimate of its work, compared with the present methods of building roads.

I.—The dividends of railroads are cut down, while the charges of doing the work are increased, by constant drainage on the income of the companies to pay interest on borrowed money, which has been invested in extravagant construction. In a paper just prepared for the American Society of Civil Engineers, I have treated this subject in some detail, drawing my illustrations from the line of road we are about constructing. I ask your indulgence while I refer to a single instance in support of the proposition I have made.

It is customary in this region to build the road-beds of railroads uniformly 18 ft. wide in excavation, and 14 ft. wide in embankment, without reference to the position of the work, whether a light bank or a heavy one ; whether the cut is shallow, through a level plain, deep under a side-hill or containing a steep grade that will assist in draining it.

The banks, also, are built of uniform width, without reference to the question of height, although a slope 20 ft. long is exposed to 210 times the liability of damage by corrosion that is suffered by a slope 1 ft. long.

Again, it is customary to say of massive structures in wood, that "decay outruns interest," and that the true economy is to build a permanent work in the beginning.

I find it otherwise, and I apply to the railroad only the simplest rules of practice. In this section of country we witness to-day among the farmers many elegant homes ; our thrifty citizens in the country live in houses that would be ornamental in a wealthy village ; but these houses have grown like the trees under whose shade they stand. Beginning two or three generations ago in the humble log cabin or hemlock shanty, they have advanced through the intermediate stages of the wood-colored frame and the pretty white cottage with its green blinds and little front porch.

These splendid farms were begun with the tillage of 15 or 25 acres, just as the settler had one or more grown sons to assist in the work.

Is there a successful manufacturer among you who began life in any other way? Apportioning his shops to his means, he has grown each year, and if he is able now to do an extensive business and build great factories, it is because he has *grown* instead of *swelling*, so that he has become rooted and strong with increasing dimensions, instead of thinly expanding to collapse with a fizz.

I would have us remember this principle in building railroads. So, by reducing the width of road-beds and making the slopes of cuts steeper than is common, and erecting temporary wooden trestles in place of permanent banks and expensive masonry, I have been able to cut down the first cost of this work $290,000, after counting a shrinkage of 10 per cent. on the negotiation of bonds ; and this estimate contemplates a road of the ordinary gauge. Now all these permanent features may be inserted in the work after trains begin to run at a greatly reduced figure.

By saving to ourselves this capital of $290,000, we have its annual income at 7 per cent., or $20,300, to devote to the work of completion. In 7 years all our slopes will have been dressed by the weather and removed by gravel trains ; while in 10 years the wood-work in the deep ravines will have been superseded by banks and the necessary masonry, and our original capital will be released to us for other purposes. We shall have ex-

pended $203,000 for work that would originally have cost us $290,000. Nor is this sum the limit of expenditure. For 20 years we shall have been paying 7 per cent. interest for the money to inexorable bond-holders, and, at the end of that time, the principal.

20 years' annual payment of $20,300 is..	$406,000
And then the original capital.....	290,000
A total of.....	$696,000

Or 3½ per cent. per annum on our original capital stock, draining away from the earnings of the road to pay for useless works.

The dividends of railroads are further cut down by the immense amount of non-paying weight carried by trains. It is estimated that the great express passenger trains of the country, with their cumbrous drawing-room and palace cars, transport 3,000 lbs. of dead weight per passenger; a labor into which they are forced by the competition of rival lines. Although extra charges are made for these luxuries, it is a mistake to suppose that passengers pay for the extra work; on the contrary, they are an onerous burden on every company which furnishes them.

Our road will escape this tax, but it must meet another. If you ride all day on any way train of the country you will observe that the passenger cars reserved for the accommodation of local traffic on roads through the least settled sections, are but partially filled during many hours of the day. An average, equivalent to 30 through passengers per car, is reckoned good work on the principal lines, and these trains move with about 6 passenger cars, weighing, with engine, loaded tender and baggage van, 360,000, or 2,000 lbs. per passenger. That is to say, for every ton of passengers that pays we carry 15 tons of dead weight without pay.

Last year the passenger traffic of the New York Central amounted to 206,000,000 passengers carried 1 mile; but they carried 306,250,000 tons of dead weight with with them, *i. e.*, 1½ tons of dead weight per passenger, exclusive of the weight of baggage.

The Erie did worse than this. They carried 128,500,000 passengers 1 mile, with 425,500,000 tons of dead weight; which is 3½ tons of dead weight per passenger.

In the freight traffic, the Central moved 474,500,000 tons 1 mile with 410,700,000 tons of dead weight, or 9–10 of a ton of dead weight for every ton of paying freight; while the Erie moved 818,000,000 tons of freight with 1,083,333,000 tons of dead weight, or 1⅓ tons of dead weight per ton of paying freight.

The old stage coach did nothing so bad as this. A Concord stage that carried seventeen passengers and a driver, bore, with its baggage, about 3,400 lbs. of non-paying weight, or 200 lbs. per passenger; that is, for every ton of passengers it carried but 1⅓ tons of dead weight.

So, too, our lumber wagons carry but ½ of a ton of dead weight for every ton of paying load.

It is true that an increased strength is demanded for the high speed of a railroad train; and also to transmit power through individual cars to move an entire train, as well as for the concussion received by stopping trains. But all these circumstances fail to constitute reasons for doing work that does not pay; and whatever dividends we get from a road, the carriage of unnecessary dead weight certainly does not pay.

What I have said is suffic ent to illustrate the proposition with which I started, of which every railroad man is aware, and every investor painfully sensible.

Were there no way out of this condition of things, we might reasonably be discouraged in our attempt to build a road that shall escape the general disappointment of hopes.

When we build canals our custom is to ascertain, as near as may be, the amount of traffic we are to accommodate, and apportion the width and depth accordingly. All our private enterprises are conducted on the same principle; but when we build railroads we seem to take leave of our ordinary wits. We say, "The New York Central, or some other, is a good road," and so taking that for a model, we build through the agricultural districts, where we shall run for the first year not more than 8 trains a day, a road costing as much as one that passes a train every half hour; that is to say, a road is built and stocked that our traffic demands the use of it for less than 1 hour in the 24, and during the remainder of the time, or during 11½ months of the 12, the whole of this immense capital is lying idle. Is there any other business,

known among men, that is done in the same stupid way?

The first proposition, then, is to build, as nearly as possible, a road that will be worked well up to its capacity, with a traffic, the reasonable increase of which will require an increase of capacity.

Such a road will accommodate 2 trains in the hour each way, and if worked with a telegraph will be as safe as any double track line in existence.

As to the luxury and spaciousness of cars and speed of trains, I am satisfied that our accommodations should be arranged and our road worked for the great paying business and middle classes, instead of for the less numerous, more fastidious and more exacting wealthy pleasure seekers.

II.—A road to answer all our requirements will be found in the class known as Small Gauge Railroads, which are now exciting the popular and professional mind of this country and Europe.

In this connection, as touching the question of gauges, it is an interesting fact, that the Great Western English line, and other broad gauge roads in America, are getting rid of their systems as rapidly as possible. They have been laying a third rail, of the ordinary gauge; (4 ft. 8½ in.), for which alone they buy rolling stock. When the plant on hand, adapted to the broad gauge, shall have been exhausted, one of the original rails will be removed, and those roads will become one with the system generally in vogue. Such a result on the part of those great works proves a very important fact. They have made all the expenditure necessary for broad gauge lines, and have built permanent works for such lines. These they are abandoning after having worked them for years, for the sake of the saving in operating. The *operation* of these railroads and not the interest on the cost of construction, is the great drain on their resources, which alone they are now able to check.

We must keep in mind that passengers who travel by rail will not permit any modification of plans by which their comforts are curtailed. They must have the same accommodations on the new lines that other companies have been giving them in the past.

But the point is, to do this more cheaply than it has been done. We begin to see that we have been laying breadth of road at extravagant cost for the sake, apparently, of throwing away its length. Thus, on our own line we must build 80 miles of road; in this matter of length we have no selection. Our duty, then, is to use up as much of this element, which will otherwise be wasted, as is possible, and save in the width, where we are permitted a choice, and are thus able to economize.

On this principle the Welsh railroad, connecting the Slate Quarries of Festiniog with Port Madoc, 13 miles distant, is built and operated.

That road has a gauge of about 23½ in., and cost an original capital of $180,000. From its earnings the Company has re-constructed the line in the most complete manner, erected workshops and manufactured rolling stock, until the expenditures have amounted to $430,000 in 5 years, all which has been capitalized. Notwithstanding this they declare an annual dividend of 12½ per cent. on the entire outlay, and their net profits have, from the beginning, been more than 40 per cent. of the original capital.

The success attending lines of small gauge railroads has been so uniform, that last year the officers and contractors of the Poti and Tiflis Railroad, 220 miles long in the Caucasus, recommended its adoption to the Russian Government. The recommendation carried the more weight, that the construction of the line was far advanced, and 10 miles of track laid on the standard Russian gauge of 5 ft. The Russian Minister of Public Works, Count Bobrinskoy, sent for the English Engineer, Mr. Fairlie, who went to St. Petersburg to explain the new system in detail.

The result was the appointment of an Imperial Commission, of the best engineers of the Empire, who visited England especially and gave the greater part of their attention to the Festiniog road, which I have mentioned.

The Indian Government, at the same time, appointed a Commission of English engineers to accompany the Russian Commissioners in their investigation, while, the spirit of inquiry seeming completely aroused, the London Board of Trade sent Capt. Tyler, Royal Inspector of Railroads, and the Norwegian Government sent Mr. Pihl, Chief Engineer of

Railroads in Norway. The Duke of Sutherland made one of the party, being not only a Director in the North-Western, but himself proprietor of a considerable length of railroad in his Sutherlandshire estates.

The result of the investigation has been entire unanimity of opinion among the members, "that the common railroad gauge of 4 ft. 8½ in. is far beyond all ordinary requirements." There was some difference of opinion as to what gauge is the best, the expression varying from 2½ to 3 ft.

Mr. Spooner, the Engineer of the Festiniog Railroad, the man who first built such a work and carried it to success, thinks a 2½ ft. gauge ample for the transaction of all ordinary railroad business.

And Capt. Tyler, the Royal Inspector of Railroads, has issued authority to the Festiniog Railroad Company to run passenger trains at any rate of speed they may desire, although when they first opened their road he limited their speed to 12 miles the hour. He declares in his report that he "travelled over this little road at 30 miles the hour with every feeling of safety."

The general conclusions, summed up by Capt. Tyler, are, that "a system of lines like this could be built, costing ⅜ of those now constructed and maintained at ¾ the expense, and would be of decided benefit to Great Britain and Ireland, and most valuable in India and the Colonies."

The 3 ft. 6 in. gauge is the standard in Norway, thanks to the good sense of her Engineer, Mr. Pihl, and Sweden has finally resolved to construct on the same gauge.

Two 3½ ft. lines are being built in Russia as a preliminary experiment.

The Brœlthal Railroad in Prussia, of 31 in. guage, is a financial success.

In France there are two private roads and one public work, the Mondalazac, of 29 in.

In Ohio a 2½ ft. railroad, 44 miles long, between Piqua and Celina, is about to be built for general traffic, through a rich and populous agricultural district like our own. This road connects with and crosses three other roads of the ordinary gauge.

A system of small gauge railroads is projected from Toledo, as feeders to the broad gauge railroads centring there.

It is now determined to build the line from Denver City to Santa Fe, more than 300 miles, on the small gauge system.

That it is the approaching system of the railroad world, intelligent men seem agreed.

An important paper read lately by Mr. Fairlie before the British Association, says "It ought to be engraved on the mind of every engineer, that every inch added to the width of a gauge beyond what is absolutely necessary for the traffic, *adds to the cost of construction, increases the proportion of dead weight, increases the cost of working,* and in consequence *reduces the useful effect of the railway.*"

In further support of what I have advanced concerning the economy of working the small gauge system, I ask your attention to some facts concerning the rolling stock of railroads.

It is customary to build cars for local passenger traffic, weighing 14 tons and possessing accommodations for 48 passengers. If such a car were filled there would be due to the weight of the car alone a load of 700 lbs. dead weight, for every passenger. But so far are these great cars from being filled in their daily runs, that a year's return from this State shows the average load on the New York Central to be only 17 passengers per car, with a load of dead weight, due to the weight of the car, of 1,840 lbs. per passenger. Referring to the figures given in a former part of this paper, we may compare the broad gauge of the Erie with the gauge of the Central, and learn that this drag of carrying a non-paying load is well illustrated in their experience. Thus the Erie road moves 3½ tons of dead weight per passenger, while the Central is encumbered with but 1½. If the doctrine of proportionate reduction hold good in this matter of gauge, then a 3 ft. road should permit equally comfortable cars, with a dead weight of but ¼ of a ton per passenger. And an actual calculation of the weight of such a car shows this to be the fact, *i.e.*, a load of dead weight of less than 500 lbs. per passenger.

III.—With this elucidation of the principle of small gauge roads, we are prepared, I think, to pass to the third and last point of this paper, namely: The application of these principles to our own purposes.

I have prepared an estimate of the cost of building a 36 in. road, and equipping it

with rolling stock, and a line of telegraph. It gives us for $1,000,000 what will cost $1,600,000 if built by the common system of 4 ft. 8½ in. gauge; a road 83 miles long, built and completed, including land damages, with all its sidings, depots and appurtenances, with a line of telegraph, and all the rolling stock necessary for 6 months' work.

I invite you to consider the full magnitude of this saving. For the $600,000 you are liable to a shrinkage on bonds of at least 10 per cent. The saving, therefore, represents a capital of $660,000, on which for 20 years, you are to pay 7 per cent. interest, or a total.....$942,000
And at the end of that time the capital..... 660,000

Thus in 20 years you will be drained of..... $1,620,000
Or 8 per cent. per annum on your capital stock of $1,000,000.

Suppose this amount saved; if, at the end of twenty years, your small gauge road is insufficient for your business, you have saved (out of your earnings if you can pay such interest) enough to build and equip a road of the common gauge, and do it without incurring debt.

* * * * *

The common car as now built, weighing 32,000 lbs. empty, hammers the rail with 4,000 lbs. on a wheel. The little car of the 36-in. gauge, weighs but 1,300 lbs. per wheel.

Similar advantages are obtained in the locomotive, which is built expressly for this system. An engine that bears 20 tons on its driving wheels, distributes 5 tons to each wheel, and with its loaded tender and its own uneffective load, weighs altogether about 50 tons, of which one-half is dead weight. In the Fairlie engine the entire load, including coal and water, is placed on the driving wheels, and thus utilized in the work of hauling the train. Instead of carrying 50 tons to procure the useful effects of 20, we have an engine weighing the 20 tons and no more; and this load is distributed over 8 driving wheels, giving but 2½ tons per wheel instead of 5, as in the ordinary engine of equal power.

So complete has been the success of the swivel-truck engine on these roads, that the Festiniog Railroad Company has already placed the 7th on their line. The reduction of weight per wheel, which they have introduced, allows us to use a rail of half the usual weight.

There were apprehensions in the minds of the managers of the Prussian railroad, that the little engines of their small gauge would be powerless in deep snow; but the result has shown them to be as effective in this as in every other position in which they have been used. The capacity of our road will be the equivalent of 1,000 tons per hour with the class of engine I have designated in the estimates; that is, 25,000 tons per day of 24 hrs., or 8,760,000 tons per year. This would be the same as 6,000,000 tons of freight and 4,000,000 passengers.

Last year the New York Central carried about this number of passengers and a half of this amount of freight. And the Erie, with 440 locomotives of the broad gauge capacity, did not reach these figures in either branch of their traffic.

I am aware that the grand objection in our case will proceed from the difficulty of making connections with other roads. But this difficulty is not so great as it seems.

On the small gauge road we can carry freight at so low a rate as to monopolize all traffic going in our direction. We present such inducements to rival connections, that we stimulate the effort to accommodate. One or other of these lines will understand that the only way of securing our work is to lay down the third light rail between their tracks.

If we build on the common gauge we are in no better position; we simply place ourselves at the mercy of one great corporation, while we cut ourselves off from other lines. On the small gauge, with a light rail, it costs but half the sum to connect with another line, and we have the choice between the two or more roads that we touch.

The law which leads any railroad to seek a port or important town, will draw them to our southern terminus with the means of taking away what we have brought. That terminus must be an important source of supply to be sought.

But we ought not to be anxious to put ourselves into the hands of any company, simply because it will accommodate our traffic with a third rail. By a simple mechanical device—an arrangement of track—we can easily and rapidly transfer

our loaded freight cars from the trucks of one gauge to those of another, and thus remain independent of the caprices of all connecting companies.

This system is pursued at Chenango Forks, where the cars of the 6 ft. gauge are sent over the narrow gauge of the Chenango Valley Road.

Let us keep in mind, that the ability to transport freight and passengers a distance of 80 miles at a cheaper rate than any competing company, makes us a power that will produce its own accommodation, so that we shall not be called on to sue for favors.

The transfer of general miscellaneous freight, such as coal, ore, grain, lumber, apples, vegetables, flour, cider and liquor in barrels, will cost—if we are able to keep our force of laborers at work constantly, with proper facilities—about 2 cents per ton.

Now, it is a matter of dollars and cents with us, not one of time, whether this is to be an unremunerative tax.

Two roads east and west of us, running parallel with our line, carried last year 100,000 passengers, and 200,000 tons of freight. Suppose we accept this as an estimate of what we may expect to do annually for a few years. The transshipment of this amount of freight will cost us $4,000. But to offset this charge, we are able to save ¼ cent. per ton per mile on our freight, and ½ cent per passenger per mile, or $80,000 on our year's work; and to this saving is to be added the $80,000 of reduced interest and capital shown in this paper to be due to the construction of a small gauge road. Here, then, is an annual expenditure of $4,000 to be offset by an annual saving of $160,000.

Is it worth while to hesitate longer on account of the difficulty of making connections?

One class of men opposes the construction of small gauge railroads; those who are interested as contractors, machinery and car builders and their dependents, among whom are railroad supply dealers, and the papers that advertise for them.

But railroad engineers, and the most intelligent capitalists who are interested in railroads, are very well agreed in this matter.

An important circumstance, as indicating what seems to be considered inevitable in this direction, is to be found in the issue of special advertisements by the locomotive and car builders, who, in spite of their prejudices and all their past interests, are preparing themselves to supply the new demand.

IRON AND STEEL NOTES.

The North Chicago Rolling Company are about to put in operation one pair of 5-ton vessels for the Bessemer process. The plant is to be established under the supervision of Mr. A. L. Holley, who acts as consulting engineer.

Works of the same magnitude, and under the same direction, will probably soon be built at Joliet.

Effects of Cold upon Iron.—The apparent undecisiveness of the experiments for ascertaining the effects of cold upon iron recently brought before the Manchester Literary and Philosophical Society, induced Mr. P. Spence to undertake a further series. He limited himself to ascertaining whether the reduction of temperature has any, and if so what, effect on cast-iron with regard to its powers of resisting transverse strain either of weight or pressure. As experiments made with iron of special quality are quite worthless for all practical purposes, Mr. Spence was careful to obtain such as might be considered as generally obtainable in the market. Messrs. Rye, Son & Ogden, of Newton Heath, carefully made 50 cast-iron bars, 3 ft. long by half an inch square, all out of one ladle, and of No. 3 Glengarnock pig, and Kirkless Hall common pig. Mr. Spence cut each bar into three lengths of 1 ft., the 150 pieces being thrown together in a heap; the ends were then covered with paint, that the new fracture might be examined; and the heap was then taken into his laboratory, so that it had three chances of perfect mixing. A boy 11 years old now handed him the pieces singly from the heap, and he placed them alternately one by one in two lots, until he had got 70 pieces in each lot. One lot was placed in a freezing mixture, standing at zero, for nearly 48 hours, and the other lot was put into water at 70 deg. Fahr., chiefly that the pieces might be broken wet, as those would necessarily be when taken out of the freezing mixture. The distance between the supports was exactly 9 in. in every case; and Mr. Spence's experiments prove that "cast-iron, having at 70 deg. Fahr. a given power of resistance to transverse strain, will, on its temperature being reduced to zero, have that power *increased* by 3 per cent." At the temperature of 70 deg. Fahr., the maximum breaking weight was 4 cwt. 3 qrs. 26 lbs., and the minimum 2 cwt. 2 qrs. 14 lbs., equal to an average of 3 cwt. 3 qrs. 6 lbs. At zero, the maximum breaking weight was 4 cwt. 3 qrs. 13 lbs., and the minimum 2 cwt. 3 qrs. 10 lbs., equal to an average of 3 cwt. 3 qrs. 11 lbs. The difference, therefore, is but 5 lbs., or less than 12 per cent., increase by the reduction of temperature. Adding together, however, the breaking weights of the 70 samples tested at 70 deg. Fahr., the total is 263 cwt. 3 qrs. 18 lbs., equal to an average of 3 cwt. 3 qrs. 10¼ lbs. The total breaking weight of the

70 samples tested at zero was was 276 cwt. 3 qrs., equal to an average of 3 cwt. 3 qrs. 22¾ lbs. The difference thus shown is 12½ lbs., or about 3 per cent. increase, as Mr. Spence states.—*Mining Journal.*

SUMMARY of abstract of experiments on the tensile strength of steel, made at H.M. royal gun factory, Woolwich; showing the average strength of each kind of steel tested, and the increase obtained by tempering:

Name of Contractors.	Nature of Materials.	Number of Specimens.	AVERAGE BREAKING WEIGHT in TONS per SQ. INCH.					
			When tested as received from Contractor or taken from Gun.	After being tempered in Oil at				Tempered in Water.
				High heat.	Medium heat.	Low heat.	Tempre. not stated.	
Krupp & Co	Cast Steel	9	32.095	65.395	54.365	56.440	....	....
Firth & Sons	Steel	3	34.436	....	....	....	....	....
Firth & Sons	Homogeneous Steel	217	31.640	47 720	47.96	47.04	44 43	....
Cammell & Co	Steel	2	26 595	....	....	....	....	....
Cammell & Co	Homogeneous Steel	61	29.48	54 575	45 66	51.505	48 966	51 110
None given	Steel	4	31.720	....	....	....	86 610	....
None given	Homogeneous Steel	36	28.967	....	37.18	....	89.53	53 93
None given	Styrian Steel	8	56.150	....	82.15	....	....	....
Moser & Co	Steel	7	33 466	54.60	56.80	....	....	....
Whitworth & Co	Steel	2	38.200	....	48 20	....	....	....
		349						

POWDERED COAL FOR IRON SMELTING.—A surprising effect is produced in the operation of burning powdered coal, in several English furnaces owned by a gentleman named Crompton. The method was devised for the purpose of economizing fuel, and to save from loss the immense quantity of small coal wasted; and it consists in blowing the powdered coal into the furnace, and exactly the quantity of air requisite to effect complete combustion. A mass of flame of the highest temperature thus fills the furnace, and does its work without producing any smoke whatever.

BERARD'S PROCESS OF MANUFACTURING STEEL DIRECT FROM PIG IRON.—The enormous and increasing demand for steel has naturally directed attention to the cheapest method of manufacturing metal, which seems destined, for certain purposes, to supersede both cast and wrought iron. The Bessemer process is well known, having been for some years before the public. But a rival now appears in the field in the system of M. Berard, adopted at the steel works at Givors, Rhone, France, and now introduced to the notice of manufacturers in this country by Messrs. Whitney Partners, Hunsletroad, Leeds, who publish translations of M. Berard's pamphlets, and are his sole representatives in England. The principal points which M. Berard keeps in view in his process are as follows:

1. The employment of gas acting at once as a calorific and reacting agent in purifying the iron by a partial purification before throwing off prejudicial bodies (such as sulphur, phosphorus, arsenic, etc.)

2. The being able to employ iron of a secondary quality, to obtain steels for certain special purposes, such as rails, tyres, etc.

3. By the combined action of air and gas being able to act alternately by means of oxidization and reduction in keeping the waste at a minimum; and by decarbonization and recarbonization regulate at will and with certainty the nature of the product to be obtained.

4. Organizing a plant which shall permit of working under the most economical circumstances.

In carrying out these principles the first point has been to secure a good gazogene. This has been effected by making an incandescent bed of coke at a high temperature traverse the gases. The decomposition of the tar and steam is rendered complete, and there is no trace of carbonic acid, while to increase the production of pure gas, particularly hydrogen, a jet of superheated steam is introduced, which aids at the same time to carry off the gases. The iron is run in a liquid state into the movable bed of the converting furnace. Two descending tuyeres, one on each side of the furnace, and having a divergent direction, are introduced into the metallic liquid, so as to cause each portion of the metal to come under the action of the current, which provokes a violent ebullition and produces a natural mechanical puddling. A simple arrangement allows the proportion of air and gas to be varied during the operation. When air is in greater proportion, the reaction is of course oxidizing, and it is reducing if the gas is increased beyond a certain point. During oxidization the temperature is considerably raised by the combustion of the carbon contained in the iron, the silicum, manganese, and a small quantity of the iron. The sulphur and phosphorus are transformed into sulphuric and phosphoric acids, which may be partly volatilized or may enter into the scoriæ. During reduction, the oxide of iron alone is reduced. The silica

combines with the oxide of manganese and the other bases in order to form silicates, which constitute the scoriæ of the bath.

The operation takes from an hour to an hour an a half, and the results of frequently renewed tests towards its close determine the point of decarbonization of the metal, and the instant at which this should be arrested in order to obtain the quality of steel desired.—*Mechanics' Magazine*

PRODUCT OF THE LAKE SUPERIOR IRON MINES IN 1870.

Names of Mining Companies, and Mines Worked on Lease.	Gross Tons of Ore Shipped by		Other Shipments.	Totals.
	Marq. and Ont. R. R.	Peninsula Division Chi & N. W. R. R.		
Jackson Mine	5,086	113,104	4,520	122,710
Cleveland Iron Mining Co.	50,129	82,755	....	132,884
Lake Superior Iron Co.	166,582	.....	....	166,582
Barnum Mine Iron Cliff Co.	.....	44,793	.....	44,793
Foster Mine, Iron Cliff Co	.....	23,458	.....	23,458
Washington Iron Co.	79,762	.....	.....	79,762
Pittsburg and Lake Angeline Iron Co.	21,232	53,467	....	77,699
Champion Iron Co.	72,518	.....	643	73,161
New York Iron Co.	.....	90,702	4,107	94,809
New England Iron Co.	24,871	.....	.....	24,871
Marquette Iron Co.	3,702	.....	.....	3,702
Grand Central Iron Co.	.....	1,809	.....	1,809
McCumber Mine.	3,002	1,864	.....	4,866
Parsons' mine	1,896	.....	.....	1,896
Winthrop Iron Co	3,469	.....	.....	3,469
Grand Total	435,249	411,952	9,270	856,471
Product of 1869				643,238
Increase				213,223

Pig Iron Produced for the Year 1870.

	Gross tons.
Morgan Furnace	5,952
Champion Furnace	5,576
Michigan Furnace	4,858
Greenwood Furnace	3,992
Bancroft Iron Co.	3,710
Collins Iron Co.	4,100
Pioneer Furnaces	5,653
Deer Lake Iron Co	2,500
Schoolcraft County:	
Schoolcraft Iron Co.	2,809
Bay Furnace Co.	3,498
Delta County:	
Fayette Furnace (estimated)	5,000
Total pig iron product	47,848
Product of 1869	38,504
Increase	9,344

Shipped as follows:

By Marquette & Ontonaga R. R.	27,399
By Pennsylvania Division C. & N. W. R. R.	8,515
Other shipments	10,250
On hand at the furnaces	1,684
	47,848

Total shipments over the M. & O. R. R.:

	Gross tons.
Iron ore	435,249
Pig iron	27,399
	462,648

Total shipments over the Peninsula Division C. & N. W. R R.:

Iron ore	411,952
Pig iron	8,515
	420,467

Total Amount of Ore and Pig Iron Produced.

	Iron Ore, Tons.
1856	7,003
1857	21,000
1858	31,035
1859	65,679
1860	116,998
1861	45,430
1862	115,721
1863	185,259
1864	235,123
1865	195,256
1866	296,872
1867	460,320
1868	498,290
1869	643,238
1870	856,471
Total	3,768,695

	Pig Iron, Tons.
1858	1,629
1859	7,258
1860	5,660
1861	7,970
1862	8,590
1863	9,813
1864	13,832
1865	12,283
1866	18,437
1867	30,911
1868	36,425
1869	38,504
1870	47,848
Total	293,160

Total Amount and Value of Iron Produced.

	Tons, Iron Ore.	Tons, Pig Iron.	Value.
1856	7,003	....	$28,000
1857	21,000	....	60,000
1858	31,035	1,629	249,202
1859	65,679	7,258	575,529
1860	116,998	5,660	736,496
1861	45,430	7,970	419,401
1862	115,721	8,590	984,977
1863	185,259	9,813	1,416,935
1864	235,123	13,832	1,867,215
1865	195,256	12,283	1,590,430
1866	296,872	18,437	2,405,960
1867	460,320	30,911	3,475,720
1868	493,290	36,425	3,676,705
1869	643,238	38,504	4,973,435
1870	856,471	47,848	5,339,804
Total	3,768,695	239,160	$27,799,809

ST. LOUIS AS A STEEL MANUFACTURING CENTRE.—The St. Louis "Republican" urges the fact upon the attention of its readers that that city might in a few years become the Sheffield of America, if enough capital and enterprise are applied to the development of its superior facilities for the manufacture of steel ware. The "Republican" shows that in the Shepherd Mountain district, within a few miles of the city, there are exhaustless quantities of the best ore for the manufacture of steel of the choicest and most serviceable qualities. Mr. Otto Worth, a practical iron analyst of Pittsburg, has lately made an analysis of the pig iron of the South St. Louis Iron Company, and finds that the metal contains the following component elements in the proportions given below:

Silicon	2.98
Carbon (1.68 combined, the rest graphite)	4.21
Sulphur	.002
Phosphorus	.067
Iron	91.97
Slag	.77
	99.999

In his report upon the analysis, Mr. Worth says: "It is an excellent iron, very well adapted to the Bessemer process, as it contains carbon and silicon enough to work very hot, and is free enough from sulphur and phosphorus to make neutral steel—neither cold nor red short. It is also the best material to be used in the so-called Siemens-Martin process." On the strength of this and other scientific endorsements, the "Republican" urges that an immense and almost immediately lucrative field of industry is open to the capitalists of St. Louis; a field in which the already great demand is certain to experience a swift and permanent growth. The "Republican" announces that rolling mills for the manufacture of steel rails will soon be in operation in the city; and several of the railroad companies propose undertaking the manufacture of their own rails. A prospectus for cast-steel works at St. Louis has also been prepared, which estimates the required capital at $1,500,000, and the production at 30,000 steel rails per year, with a profit of $1,200,000. At $100 per ton, the present price, the resulting value would be $3,000,000. Supposing this estimate to even approximate accuracy, the promise seems great enough to encourage the liberal investment of capital.

OIL FUEL FOR IRON SMELTING.—A day or two ago a trial was made at the Illinois Central Railroad shops, of the value of Whipple & Dickenson's petroleum fuel, in a smelting furnace. It was a most satisfactory and pronounced success; a white or melting heat being reached in just 53 min. from the time of starting the fire. To attain this result it has always taken, before this, 4 to 4½ hrs., and the consumption of a large amount of coal. The Illinois Central Company and its employees are highly pleased with obtaining a better heat in so little time and so cheaply.

DEMAND FOR STEEL RAILS.—"Herapath's Railway Journal" (London) says: "We hear that every steel rail manufactory in the country is now in full orders for the next 2 years, and that the price of the best Bessemer steel is some £12 per ton. The difficulty now appears to be not to pay for steel rails, but to get them. This great demand for them arises from the marked economy in their use. Considerable savings are being made by our railway companies in the maintenance charges, due to steel rails. Thus experience has already supported theory as to the great advantage of steel rails."

RAILWAY NOTES.

DELAWARE AND HUDSON CANAL RESERVOIR.—It is reported that the company have purchased a large tract of land in Sullivan county, about 7 miles from Wurtsboro', upon which is Lord's Pond, a large inland lake. Upon this land they have commenced the construction of an immense reservoir, which will be fed by waters from the pond, and, in time of need, will add its supply to the canal, and prevent even such a drouth as that of last year from affecting transportation. The reservoir will cover 209 acres. The dam will be 923 ft. in length, and 23 ft. in height, giving a "head" of 20 ft. It will require, above the base line, 7,000 cubic yds. of earth for the sloping embankment above the dam, and 3,000 yds. of dry masonry and 320 yds. of cement masonry for the bulkhead. The work will cost, it is estimated, about $15,000.—*Railroad Gazette.*

BALTIMORE AND OHIO RAILROAD SHOPS.—At the Mount Clare shops of the company they are busy building ten-wheeled freight engines, of what will seem to railroad men of a higher latitude somewhat peculiar construction. They are ten-wheeled engines, with 6 driving-wheels 50 in. in diameter, and have cast-iron tires, which are used exclusively on this road. The distance from the centre of the back driving-wheels to the centre of the truck is only 15 ft. 4½ in. This makes it necessary to place all the driving-wheels ahead of the fire-box.

The cylinders are 19 in. diameter and 22 in. stroke, and are inclined at an angle of about 1 in 6. The valve gear is the old double-expansive valve, worked by eccentrics and hook motion. The cab is on top of the boiler, and the fire-box is inclined downward from the top of the barrel of the boiler. The crown-shut is stayed with stay-bolts, the same as the sides of the fire-box. The grate is 59¼ in. long × 42¼ wide. The boiler has 134 2¼ in. tubes, 14 ft. long. The shell is 48 in. in diameter, made of ⅜ in. iron, and double riveted all through. The fire-box is made of steel, with the exception of the tube-shut, which is made of copper.

These engines weigh 73,000 lbs. in working order. We could not learn the relative weights on the drivers and on the truck.

Although these locomotives may appear somewhat antiquated, yet, after long experience with freight engines of different kinds on this road, it was thought that those of the plan described gave better results than any others. It must be remembered, too, that they are obliged to work on curves of 400 ft. radius, for which they are especially adapted by the shortness of their wheelbase.

The first engines of this plan were designed by Mr. Samuel J. Hayes, now Superintendent of Ma-

chinery on the Illinois Central Railroad, in 1853 or 1854.

The Baltimore and Ohio Railroad Company has built 10 of them for the Pittsburg and Connellsville Railroad, which has just been opened.

About 1,500 hands are now employed at the Mount Clare shops.

INDIAN RAILWAYS.—A survey party has commenced operations on the proposed Indian state lines from Indore to Ajmere. The line will pass *via* Ullmuch, but the route generally has not yet been settled. The surveying party comprises Mr. Miller, superintendent; Lieutenant Firebrace, R. E., Lieutenant Dundas, R. E. (from the public works secretariat, Calcutta), Captain Downing, from the topographical survey, Lieutenant Begbie, R. E., etc. M. Le Messurier, the agent of the Great Indian Peninsula Railway, Mr. Conder, the general manager, and Mr. Middleton, the district traffic manager, have been inspecting the works in progress between Goolburgh and Raichore. Everything is stated to be going on well.

IT is not yet 2 years since the great Union Pacific line of railway was opened throughout its 3,361 miles of length, from New York to San Francisco, and already American enterprise is sighing for fresh fields to conquer. It is not enough that two other great lines connecting the east and west coasts should have been projected—one at the extreme north and the other at the extreme south of the United States,—nor that the most northern of these should have been already commenced. Such triumphs would be but tame repetitions of that already won. Nothing less will suffice than the solution of a problem which has been the despair of all the generations since Cortes. The American isthmus must be cut, and sea joined to sea. The thing has been done indeed, so far as travellers were concerned, years ago. The railway across the isthmus of Panama was projected immediately upon the discovery of the Californian gold fields, and opened to traffic so far back as 1855. For commercial purposes, however, this line has proved almost worthless, both on account of the expenses and danger of transshipment, and the badness of the harbor on the Atlantic side. Experience has now also shown that the great Pacific Railway is quite inadequate to supply the needs of a through commerce between the Atlantic and Pacific oceans. This project of cutting a canal across the American isthmus is, as we have said, anything but a new one. Above a dozen routes have been projected, and three or four have been actually surveyed. Of these, apparently by much the most feasible is that through the river San Juan and the great lake of Nicaragua. The dividing neck of land between Nicaragua and the Pacific is actually only about 15 miles in breadth. But to cross this a deep cutting of 2 miles, a tunnel of 1 mile, and descent of 200 ft. by locks would be necessary. The grand object of search has always been a route which, like the Suez Canal, should be practicable without any locks at all. At last it is believed that this has been discovered. Two expeditions are engaged in the work of exploration; and one of these, under Commander Selfridge, professes to have been most successful. A New York correspondent states that the new route is projected to run from the Gulf of Darien on the Atlantic to the Gulf of San Miguel on the Pacific, and has deep and capacious harbors at both ends. The total length from sea to sea would be about 120 miles, but the length of the canal itself, connecting the rivers Atrato and Tuyra, would be less than half that distance. The highest level to be crossed would be about 170 ft. above the sea level, and 200 above the highest river level; but the rock at this point is friable, and might easily be cut. The estimated cost is about £5,000,000, and the time necessary to complete the work about 5 years; but, of course, these estimates must be conjectural. Still, it really seems as if there were a fair chance that a second cutting, of even greater importance to the commerce of the world than that at Suez, would speedily be made. The voyage from New York to Kohohama would be shortened by 8,000 miles. From Liverpool the Suez route would still be 1,500 miles shorter than the Darien, but the Darien would be a good deal the safer. The Americans are getting considerably excited about the matter, as they well may; and San Domingo acquires a new importance in their eyes as a great trading station of the future.—*Mining Journal.*

ENGINEERING STRUCTURES.

THE PROPOSED INTERNATIONAL BRIDGE AT BUFFALO.—The construction of the new bridge across the Niagara river at Buffalo, will establish another and important connection between Canada and the United States. The value and importance of an international bridge at this point has long been acknowledged by those interested in the railway system of the two countries, and the work of building it would long since have been undertaken if unity of action could have been obtained among the different railway interests which are to be benefited by it. It is now to be undertaken by the Directors of the Grand Trunk Railroad of Canada, and although a private enterprise as far as its ownership is concerned, it will be of great value to the railroad systems of both countries. It will be, in fact, a short connecting link through which will pass the direct and indirect traffic from at least a score of American and Canadian railways.

The locality selected offers unusual facilities for the construction of such a bridge, and the completed work promises to yield a handsome profit upon the capital invested. A small island, lying about midway between the American and Canadian shores, affords facilities for sinking the foundation and building the central piers, and in this respect it will differ very greatly from the suspension bridges which span the rapids below the falls of Niagara. The new bridge will have a carriage and footway for passengers and ordinary vehicles, as well as its double track railways for trains. Its entire cost will not exceed $1,250,000. It is undertaken under an Act of the Dominion Government, and also an Act of the United States, which declares it to be a postal road, and to be available for the use of all railway companies, upon payment of the same rates and tolls as are charged upon other parts of the Grand Trunk line. The Directors of the Company are clearly within the mark when they estimate the increase in their traffic at half a million dollars a year, and it is not improbable that the net profit upon the increase of business will alone equal the amount. We have not yet received any detailed statement

of the plan upon which the new bridge is to be built, but it is said that no trouble or expense will be spared to make the structure in all respects the strongest and best of its kind on this side of the Atlantic. The work will be intrusted to competent hands, and will be pushed to completion without unnecessary delay. The construction of central piers of substantial masonry will render the bridge better adapted to railway purposes than one crossing the river with a single span, and when it is possible to build such piers without impeding navigation, we think the long span may be advantageously dispensed with.—*Iron Age.*

PLATT RIVER BRIDGE.—Mr. J. B. Moulton, Chief Engineer and General Superintendent of the Omaha and Southwestern Railroad, is engaged in making surveys for the bridge over Platt river about 7 miles from the junction with the Missouri river. The Nebraska Legislature has offered 20,000 acres of land to aid the undertaking. One location that has been made, but not yet finally decided upon, requires one span of 150 ft. over the first channel; 3 spans, in all 500 ft., across a towhead of Cedar Island; 400 ft. over the main channel; 1,000 ft. of trestle work on the island, and 800 ft. of trestle work on the south bank—in all 2,850 ft. In crossing the main channels, the engineers have partially located the bed-rock at a distance of 60 or 70 ft. below the bed of the river. With the exception of one strata of coarse gravel and loam, with perhaps another of bituminous shale, this deposit upon the bed-rock is a fine sand.—*Railroad Gazette.*

FROM the report of the proceedings of the Institute of Civil Engineers we extract the following description of a wrought-iron pier at Clevedon, Somerset, by Mr. John William Grover, M. Inst. C. E.

In this communication the author stated that the Act for constructing a pier at Clevedon was obtained in the session 1863-4, but little was done upon the ground till the spring of 1868, which was singularly boisterous and unpropitious. The works were virtually completed at the end of the same year, and had since stood well, without material damage.

The coast of Somersetshire at this spot was composed of dark cliffs of magnesian and mountain limestone, of which large fragments were scattered about the beach, the spaces between them being filled with soft mud. The site selected for the work was tolerably free from these obstructions, being a thin promontory of rock, level from right to left, and dipping seawards at an angle of 12 deg. to 8 deg. Beyond this came mud 13 ft. deep, upon boulders and clay. At the head, a ridge of sand 2 ft. deep covered a bed of hard red clay, giving a tolerable bottom. The chief difficulty was, however, the great rise and fall of the tide, viz., 45 ft. at springs. As the Bristol Channel was only nine miles across at this point, the water acquired the velocity of a mill-race on the ebb, or 5½ miles an hour. Clevedon was also exposed to high seas from the south-west.

The structure comprised, first an approach of masonry, 20 ft. wide and 180 ft. long, with a falling gradient of 1 in 10; secondly, the body of the pier was formed of 8 spans of 100 ft. each, supported upon piers of Barlow rail piles, spreading to a wide base at the foot and clustered at the top. From below the girders arched ribs of Barlow rails were connected to the vertical piles. The main girders of the structure were continuous, 3 ft. 6 in. deep, and 800 ft. long, the flanges being 1 ft. 6 in. wide, and all of wrought iron. The Barlow rails of the piles weighed 80 lbs. per yard each; they were riveted back to back, and were filled with a preparation of coal tar. The main girders were placed 16 ft. 6 in. apart; the seats, which were continuous, rested upon the top flanges, and the pier at the parapets was nearly 19 ft. wide. The floor was laid with close planking 3 in. thick, which ran longitudinally, and presented, with the camber of 3 in. in the middle, an appearance like a ship's deck. The sides or parapets were close boarded. Below low-water mark the Barlow rails were discontinued, and the piles consisted of solid stems of wrought iron 5 in. in diameter, screwed to depths varying from 7 ft. to 17 ft., with cast-iron screws 2 ft. in diameter.

The pier head was 50 ft. long by 40 ft. wide. From the ground line to the deck it was 68 ft. high. There were 5 lower stages or landing-decks, 10 ft. apart, connected by wide staircases. The head was composed of piles of Barlow rails weighing 70 lbs per yard each, riveted back to back; they were connected together with rolled joists, and were strongly braced by diagonal ties. The length of the longest pile was 76 ft., and the pier was accessible at low water of spring tides. One span was tested with a central load of 42 tons, when the deflection was 1¼ in. in the centre.

The weight of wrought iron employed was less than 370 tons, and of cast iron 7 tons. The cost of the work was under £10,000.—*The Engineer.*

THE steamships Africa and Great Northern, loaded with the section of submarine cable to be laid between Shanghai and Possiette Bay, on the Russian-Chinese frontiers, for the Great Northern Telegraph, China and Japan Extension Company, are probably on their way out. They were to leave before May 1st.

NEW BOOKS.

REPORT ON CERTAIN EXPERIMENTAL AND THEORETICAL INVESTIGATIONS RELATIVE TO THE QUALITY, FORM, AND COMBINATION OF MATERIALS FOR DEFENSIVE ARMOR. Made by direction of Brevet Major-General A. A. HUMPHREYS by Brevet Major W. R. KING, Captain of Engineers. Washington: Government Printing Office. For sale by Van Nostrand.

A voluminous and well printed work, and is without doubt an exhaustive treatise upon the important subject of defensive armor. It is illustrated by 28 lithographic plates.

IRON AND HEAT. By J. ARMOUR, C.E., 1 vol. 18mo. London: Lockwood and Co., 1871. For sale by Van Nostrand.

In "Iron and Heat," Mr. Armour has collected in the compass of 164 pages, the fundamental principles and facts concerned in the construction of iron beams, pillars, and bridge girders, and the action of heat in the smelting furnace. The mechanical portion is illustrated by 55 diagrams, some of which are quite new and highly ingenious. The work is designed to benefit those who are more intimately acquainted with practical operations as workmen than with the principles

on which that practice is based; common arithmetic only is used, and the author successfully carries out his "endeavor rather to explain circumstantially the rules of common use than to develop new theories." The sections on iron smelting are rudimentary, but the action of heat in its various operations inside the furnace upon the different materials concerned is so closely followed that the essential conditions of the smelting process may be easily understood. The volume is a suitable and useful addition to Weale's celebrated series.

FRAGMENTS OF SCIENCE FOR UNSCIENTIFIC PEOPLE. By JOHN TYNDALL, LL.D., F. R. S. London: Longmans, Green & Co. 1871. For sale by Van Nostrand.

This new work of Professor Tyndall's is a series of detached essays, lectures, and reviews, not quite new except in the form of a collected volume. It contains the papers on Dust and Disease, and various others, such as an essay on the Constitution of Nature, from the "Fortnightly Review;" Thoughts on Prayer and Natural Law, an extract from Mountaineering in 1861; on Miracles, and Special Providences, a review from the "Fortnightly," on Matter and Force, a lecture at Dundee in 1867; an address on the Scope and Limit of Scientific Materialism in 1868; one on the Scientific Use of the Imagination, delivered before the British Association at Liverpool; a "Rede" lecture on Radiation; a discourse on Radiant Heat; one on Chemical Rays and the Light of the Sky; one on Faraday; a lecture on Magnetism; and others, including some shorter articles on Slates, Miracles, Science, and Spirits, etc.

Mr. Tyndall's writings, while full of scientific interest, are often rhetorical and poetical; and the delusive "Spirits" of whom he speaks do not seem to have been far wrong, in one thing at least —namely, in styling him "the poet of science," which they declared to be already his name in "the other world."

THE SEVEN PERIODS OF ENGLISH ARCHITECTURE DEFINED AND ILLUSTRATED. By EDMUND SHARPE, M. A., Architect. Second Edition. London: Spon. Birmingham: Birbeck. 1871. For sale by Van Nostrand.

The second edition, recently published, of Mr. Sharpe's "Seven Periods" is enlarged chiefly by eight additional plates of Lincoln choir, nave, and presbytery, and Peterborough choir. In these days of masterly scratches and meagre lithographs it is refreshing to see a set of well-finished, clear, and precise line engravings, reminding older readers of the days of Le Keux. Mr. Sharpe's divisions and titles have been set forth and reviewed on several occasions in these pages, so that we need not just now again discuss them. Readers, without being bound to substitute the terms *Curvilinear* for "Decorated," and *Rectilinear* for "Perpendicular," will find the characteristics of the various periods of English architecture succinctly and clearly set forth, and will be sure to derive advantage from a study of the book. The illustrations make a capital set of copies for architectural students.

GEOLOGICAL SURVEY OF OHIO. Part 1. Report of Progress in 1869. By J. S. NEWBERRY, LL. D., Chief Geologist. Part 2. Report of Progress in the Second District. By E. B. ANDREWS, Assistant Geologist. Part 3. Report on Geology of Montgomery County. By EDWARD ORTON, Assistant Geologist. Columbus: Nevins & Myers. For sale by Van Nostrand.

This affords a new addition to the stock of geological information of our country. A very neat map is folded in the volume, giving by colors the extent of each of the groups of rocks. A chart in another place exhibits the parallelism between the Ohio and New York series, and shows also the relation of each to the European rocks.

The triple report occupies 176 pages.

THE JOURNAL OF THE IRON AND STEEL INSTITUTE. This journal, of which the first number has recently appeared, promises to be of exceeding interest to all who are directly or remotely concerned in the metallurgy of iron and steel.

Number one contains 276 pages, and several engraved plates.

The contents in this and future numbers is comprised under the following classification:

1st. Proceedings of the Institute and of the Council, with reports of the meetings.

2d. Original papers and communications relating to the manufacture of iron and steel.

3d. A short general report of the statistics and progress of the manufacture and trade in Great Britain, since the appearance of the previous number.

4th. A similar report as to what has been done elsewhere throughout the world, with references to the original sources of such information.

A large portion of the present number is occupied by Mr. J. Lowthian Bell's paper on the chemistry of the blast furnace.

The next number may be expected within a period not exceeding three months.

PRELIMINARY EXPERIMENTS ON THE MECHANICAL AND OTHER PROPERTIES OF STEEL, MADE OR COLLECTED BY A COMMITTEE OF CIVIL ENGINEERS. London. For sale by Van Nostrand.

These tabulated results of careful experiments are exceedingly valuable.

The specimens tried are of well-known brands, and the tests to which they are subjected are such as to make known the peculiar virtues of each manufacture.

A summary of these tests is given in another place in our present issue.

The experiments were directed by Mr. Kirkaldy.

MISCELLANEOUS.

AMERICAN EMERY.—The existence in the United States in reliable quantity of so rare and useful a mineral as emery, and its successful introduction into use, are two interesting facts; and the latter marks an important stage in our progress in manufacturing. The Ames Manufacturing Company, of Chicopee, Mass., has been long celebrated for the excellence of its swords, bayonets, bronze cannon, etc; and many not familiar with these articles will remember the famous bronze doors in the Capitol at Washington, as well as the various Colossal Bronzes from their works which adorn Union square, N. Y., and other public squares and grounds throughout the country. It is an auspicious circumstance that a man of the practical skill and the high reputation of the President of

the Ames Manufacturing Company should be responsibly connected with the manufacture of this emery. There can certainly be no reasonable doubt of the genuineness of the mineral or of the faithfulness of its preparation.

We have devoted some thought and inquiry to this subject, deeming it of interest to a large portion of our readers. Until so recently as 1868, the emery trade of the United States seems to have been wholly in the hands of those who manufacture and sell the emery mined in Turkey. Many of the foremen and grinders being foreigners, and none of them knowing even of any but imported emery, the line of foreign occupation seemed not only complete, but formidable. If "possession gives nine points," the tenth was surely in the same hands, by reason of the intense prejudice against any "new emery," and most of all against any such article of American mining.

To aid in thus holding the market by the imported article, the duty on the Turkish ore has since been removed, and since 1869 the list price of the emery ground from it has been twice lowered.

Still the American mined emery has vigorously and rapidly made its way; and many of the largest consumers and most critical judges of emery not only would decline the best foreign emeries at the same price, but use the American to the exclusion of all others. This we find to be specially the case with the cutters of the precious stones, and manufacturers of lenses for optical instruments, spectacles, etc. The grinders of the hardened steel also speak in equally strong terms of this emery. If it meets the wants of such consumers as these, we do not see how it can fail of satisfying all who grind softer materials. The recent extensive introduction of "solid emery wheels" has widened the range of use for emery, and a maker of these wheels tells us that in turning them off with a diamond tool to prepare them for use, he finds the Chester emery to resist and cut his tool more vigorously than the best of the imported emeries.

Such facts as these certainly seem to be the best possible auguries of success, and the eminent firms engaged in selling the Ames' Chester emery throughout the country are the last men who would sell an inferior or even a second rate article. This is much to accomplish in so short a time.

The appearance of one or two imitations may perhaps be taken as an evidence of its excellence. A worthless article would be hardly worth imitating The quiet but still successful introduction of the genuine Chester emery could only have been effected by an article of intrinsic merit; and we think our readers will agree with us that it constitutes a real and interesting advance in American manufacturing interests.—*Iron Age.*

NEW ROAD MATERIAL.—It has often been remarked that of all streets London streets are the dirtiest in wet weather, the dustiest in dry; and for 9 months out of the 12 not only positively dangerous to travel upon, but damage our horses, carriages, and even our temper to an alarming extent. Who has not seen frequently horses thrown down, and almost cut to pieces, from the looseness of the material of which our roads are made?

It is well known that hitherto the principal material used in road making and repairing is the broken granite from the quarries of Guernsey or those of Leicestershire, and the very nature of it is quite sufficient to account for our discomfort. For building purposes, perhaps, granite is the most lasting, under a condition of rest; but when placed on roads, and subjected to the crushing and grinding operation of wagon-wheels, it quickly becomes reduced to powder, and, having no cementing properties, is in dry weather blown into our houses, or converted into mud in wet, bespattering our persons, if we are unlucky enough to be obliged to walk. It is not our present intention to remark upon the asphalt which has been laid down in one or two of our principal thoroughfares, as its first cost will deter most of our vestries from adopting it, and time alone can show its value. But in meantime attention may be called to the fact that we possess, to an almost boundless extent, a material in every degree superior to granite. This is the Ironstone slag, and for the benefit of our readers not connected with the iron trade, we may slightly digress to explain what this is.

In the production of pig-iron from the raw material there is a large amount of dross, which flows from the surface of the molten metal in the furnace, and is received in what are called "slag boxes;" these when filled are drawn away and emptied to waste, and this material when cold assumes a pale French gray color, and is what we now designate "Ironstone slag." From an analysis nowbefore us there can be no doubt of its cementing properties—its greatest value; and the fact that in Belgium and France it has been moulded into an almost endless variety of forms, both for building and road-making, should be sufficient to convince us of its utility. For the formation of a road it should be broken into paving blocks, about 6 in. cube, and packed loosely together, covered with the same broken to a 2 in. gauge about 4 in. deep, or 10 in. together; afterwards to be well watered, and rolled together to crush the whole, thus forming a road which for cleanliness and comfort cannot be surpassed. For simply repairing an existing road it is sufficient if laid on 2 in. thick.—*Mining Journal.*

THE SUEZ CANAL.—The Suez Canal has now been a twelvemonth working, and it is officially stated that the receipts average about £20,000 a month, or about £240,000 a year. The headquarters of the Company being in Paris, the war and siege have prevented the usual official report being made, which should have given information regarding the net as well as the gross revenue; but the statement as to the gross traffic affords some material for a retrospective glance at the anticipations of traffic and profit which were indulged in a twelvemonth since, and which we showed to be exaggerated. The promoters of the enterprise, it will be remembered, did not shrink from calculating on a traffic of 2,000,000 or 3,000,000 tons of shipping per annum, and this immediately; and no doubt if the canal had such a traffic, it would pay very well. The canal would do very well, we said, if at first 1,000,000 or 2,000,000 tons of shipping annually made use of it. The statistics now published show that the average traffic has not yet reached the figure of 1,000,000 tons—receipts of £240,000 per annun at ten francs per ton only implying a trade of about 600,000 tons per annum. In point of fact, now that we have experience to guide us, the canal has had unexpected luck in obtaining even this traffic. The screw steamers which use it almost exclusively are of a kind which did not exist a very few years ago; and it is cer-

tain the promoters could not have foreseen that when the canal was inaugurated, not only would such steamers be in existence, but a number of them laid up, or about to be laid up, for a want of business, would be suddenly available for a new venture. But for the remarkable progress of mechanical invention since the canal was commenced it must have been a stupendous failure; and but for the singular conditions of the shipping trade at the time of its inauguration, its start, though far short of the promoters' anticipations, could not have been so good as it is. The practical question now is how the canal is to be kept open; and the gross return will, perhaps, be sufficiently good for this purpose, though we do not know yet what the working expenses have been. It will be ludicrously insufficient even to pay the debenture holders, whose annual claim is double the amount of the gross receipts; but if there is only a surplus of any sort to be dealt with, there will be some possibility of a new organization of the Company, or the purchase of its undertaking by the Egyptian Government.—*Economist.*

JARRAH JARRAH TIMBER.—One of the most important products of Western Australia, as regards constructive materials, is the jarrah jarrah wood or mahogany of those parts. The advantages of this timber are its great strength, hardness and closeness of grain, combined with durability under exposure either to salt or fresh water. It is never attacked by white ants nor by the *teredo navalis*, which abound in tropical and semi-tropical seas, and this confers upon it an additional value. It somewhat resembles red gum in appearance, but the grain is darker, finer, and closer than that of the latter wood, and it is susceptible of a very high polish, which brings out a rich dark hue. It is invaluable to the Western Australians, who use it for ship-building, pier, and railway construction, as well as for the interiors of buildings and for furniture. In proof of its usefulness and durability in subaqueous operations, we may mention that three piles were drawn last year after having been in use for 30 years at the Perth Causeway Bridge over the Swan river, Western Australia. The piles, when drawn, appeared to be as sound as the day on which they were driven in, although they were half under water the whole of the time. A piece was sawn off the whole length of each of the three piles, one surface being polished and the other left rough, so that the soundness of the timber is apparent. The facts connected with these piles are vouched for by Mr. J. Manning, clerk of the works at Freemantle, Western Australia. In contrast to this may be mentioned the circumstance attending the use of three heavy sheer-legs of Baltic timber during the construction of the same bridge. The portions of these legs which were under water were completely riddled in the course of ten months by the *teredo navalis*, while the three jarrah piles do not show the slightest signs of insect ravages after 30 years' immersion in the same water. The immunity of this wood from the attacks of insects, whether land or marine, has been proved by analysis to be due to the presence of tannic acid in the wood.

Although this valuable wood has hitherto been but little known beyond the colonies, it will doubtless shortly come into more general use, as a company has been formed for supplying the market on a large scale. It was organized about two years since, under the title of the Western Australia Timber Company, and the Government ceded to it 320 sq. miles of jarrah jarrah, tooart, and karie timber country, with 2,000 additional acres of land for every mile of railway made by the company. The area selected by the company is about 12 miles from Geographic Bay, which lies to the north of Cape Leuwin. The works consist of a loading jetty, which was completed towards the close of last year in that Bay; a line of railway 12 miles in length from the Bay to the timber district, and mills for sawing the timber. The railway and the mills were very nearly completed when the last mails left Australia. The company anticipated being in full working order very soon, and they expect to be able to supply jarrah timber at the same price as charged for red gum—a greatly inferior timber. The company have works at Ballarat, where they have accumulated a large store of jarrah and tooart wood. This tooart wood is a species of white gum, and has a very close grain, is extremely hard, cannot be split, and is capable of enduring great heat without rending. The tooart wood has been suggested for use in gun carriages, on account of its non-liability to split. Jarrah jarrah timber is being used by Government in the construction of military barracks in Ceylon, where it is supplied at little more than half the price charged for Indian teak. Possessing such advantages as the jarrah timber does, there can be little doubt of its commanding an extensive market, and proving useful in a variety of ways, as well as remunerative to the enterprising individuals who have embarked their capital in it.

IMPROVED METHOD OF PRODUCING HYDROGEN GAS.—MM. Tessie du Motay and Marechal, who have lately discovered a mode of obtaining cheap oxygen for illuminating and medical purposes from the manganates of soda, have sought a more practical and economical method of producing hydrogen by the decomposition of water by means of carbon, and they have discovered the following method, which has given the most extraordinary results. Alkaline and earthy alkaline hydrates, such as the hydrate of potash, soda, strontium, baryta, chalk, etc., mixed with charcoal, coke, anthracite, pit coal, peat, etc., and heated to a red heat, are decomposed into carbonic acid and hydrogen, without further loss of heat than that due to the production of the carbonic acid and hydrogen. The hydrates of potash, soda, etc., and more especially the hydrates of chalk or lime, decomposed by the coal into hydrogen and carbonic acid, can be used indefinitely in this process, provided they are moistened each time with water, so as to reproduce the decomposed hydrates. In this operation, the hydrogen gas is generated without any special production of steam, and may thus be produced without any other generating apparatus than the retorts themselves. These retorts, not being exposed to the direct action of the steam, are not subject to any interior alteration or damage. It follows, therefore, that the hydrogen gas produced by the decomposition of the above-named hydrates by means of carbon can be generated at a very small cost, and with the same facility as carburetted hydrogens from the distillation of pit-coal or other organic hydro-carbon matter. These alkaline and earthy alkaline hydrates may be mixed with the

different mineral or vegetable combustibles, either in a definite chemical proportion, or without a fixed or determinate proportion, and in any suitable distilling or heating apparatus, in order to produce, when heated to a red heat, hydrogen gas for illuminating and heating purposes. The advantage of the production of hydrogen as cheaply as oxygen, which has been obtained, is likely to create a revolution in many industries, and especially in metallurgy. A cheap method of producing a great heat in order to reduce metals, such as platinum, gold, silver, and iron, has long been sought for in Europe, where the oxyhydric blowpipe is now used to melt the platinum in a calcium crucible. By this discovery it becomes possible to obtain an immense heat which could be regulated by a simple tap. Enamellers and porcelain makers may thus get rid of one of their greatest troubles.—*Journal of the Society of Arts.*

On the Melting of Lead Projectiles by Impact.—In "Poggendorff's Annalen," Mr. E. Hagenbach applies the mechanical theory of heat to account for some of the results of the experiments recently made at Basle, with the view of using targets of iron instead of wood in practice with fire-arms. Strong plates of iron were fired at from the distance of 100 paces. Conical bullets, by their impact against the iron plate, produced scarcely perceptible indentation, and fell down near the target; at the same time the lead projectile was melted to a very considerable extent. This could be recognized by the fact that around the point where the ball had struck, the plate was spattered with lead in the form of a white star; that, moreover, the melted lead was found in the vicinity, and that of the original bullet, which weighed 40 grammes, only the comparatively small portion of 13 grammes remained. By the author's calculation, the force expended on the ball gives, as mechanical equivalent of the heat, 0.49 thermal unit. He then proceeds to inquire how much heat is necessary to produce the melting described. The entire projectile (40 grammes) had to be raised to the temperature of the melting-point of lead, or near it; and the 27 grammes had to be melted. Assuming 100 deg. C. as the initial temperature of the ball, which was somewhat warmed by the heat of combustion and by friction, the melting point of lead being 335 deg. C., its specific heat 0.031, and its latent heat of fusion 5.37, he finds necessary for heating 0.29 thermal unit, and for fusion 0.15, giving a total of 0.44 thermal unit, this being only .05 less than the estimated mechanical equivalent. Thus the mechanical theory of heat sufficiently accounts for the operation. Almost all the impetus of the motion of the body is transformed into heat—a result which was indeed to be expected, seeing that the iron plate was very slightly deformed, and the projectile rebounded but little. By far the greater portion of the heat was used in heating and melting the lead. This is also readily understood; for the short time within which the entire process was effected could give rise to but littles loss by conduction and radiation.—*Engineering and Mining Journal.*

A Mississippi River Item.—The engineer officers who have charge of the surveys and improvements upon the Western rivers report that the Mississippi river is changing its channel, so that Vicksburg will soon become an inland town unless immediate preventive measures are taken. The main channel is now immediately under the bluffs upon which the town stands, making one of the best harbors upon the river, but in a few months the engineers are confident that a cut-off will be formed across a low sandy peninsula opposite Vicksburg, through which the greater portion of the current will pass, leaving not enough water at the levees of the town to float steamboats. To prevent this, it will be necessary to construct an expensive stone revetment, which it is estimated will cost $2,715,535.

The Geology and Mineral Resources of Siam.—Comparatively little has been published with reference to the geology of Siam; but a correspondent kindly furnishes a series of valuable notes as to the best sources available on the subject. Much information will be found in "Mohat, On Siam and Gambodia," probably to be found in the library of the British Museum, although it is not in the library of the Geological Society of London, nor in that of the Royal School of Mines. In Mr. J. Crawford's "Descriptive Directory of Indian Islands" (p. 379), there are some very interesting notes on Siam. They refer to a district from 4 deg. to 22 deg. of north latitude, and 1,080 geographical miles in length, embracing an area of about 111,000 geographical miles. Three mountain chains, taking a north and south direction, are referred to as running between the equator and 14 deg. north latitude; and iron, tin, and gold have been found in the continuation of the middle chain and in the most westerly part through the Malay Peninsula. The formation is sedimentary and plutonic. Between 13 deg. and 14 deg. on the western borders of Siam, lead, zinc, and antimony have been found, but never worked; but gold, which is found associated with tin, has received more attention. The noted mines of Bangtapan are between 10 deg. and 12 deg. and "Three Hundred Peaks," and have yielded some fine rubies and sapphires. Prof. Royle (*re* Banca) likewise contributed some valuable information to the Geological Society of London, in communications "On the Mines of Tenassarim Province,' which were published in their "Proceedings" between November, 1843, and April, 1845. In the "Quarterly Journal" of the same society (vol. 13, p. 188), Messrs. Moyle and Hillier give a "Notice of the Occurrence of Metalliferous Ores and of Coal in Siam," in hills extending north and south from latitude 15 deg. 25 min., near the river Chaw Phya (Meinam). In this notice was announced the discovery of apparently valuable copper veins, principally of grauwacke, also of lead and silver, and enormous beds of magnetic and specular iron. In the country to the north, carboniferous limestone, with indications of coal, has been met with, and on the eastern coast of Siam beds of coal have likewise been discovered.—*Mining Journal.*

Curious Property of Gun-Cotton.—Dr. L. Bleekrode, in a paper published in the "Philosophical Magazine," gives some account of experiments in which he tried to ignite gun-cotton with the electric spark. He thought to facilitate its explosion by wetting it with a highly inflammable liquid, as, for example, the bisulphide of carbon. But it was only this latter substance that was immediately set on fire by the spark—while the gun-cotton did not explode, but remained apparently intact amidst the burning bisulphide, presenting almost

the aspect of a mass of snow slowly melting away; the same effect is produced by moistening gun-cotton with bisulphide of carbon, ether, benzine, or alcohol, and igniting it afterwards with some flame or other; all these liquids yield the same results and are without danger, even if great quantities are used; the explanation of this, Dr. Bleekrode finds in the researches of Professor Abel, "On the Combustion of Gun-cotton and Gunpowder." These results indicate that it, even for the briefest space of time, the gases resulting from the first action of heat on gun-cotton upon its ignition in open air are impeded, from completely enveloping the burning extremity of the gun-cotton twist, their ignition is prevented; and as it is the comparatively high temperature produced by their combustion which effects the rapid and more complete combustion of the gun-cotton, the momentary extinction of the gases, and the continuous abstraction of heat by them as they escape from the point of combustion, render it impossible for the gun-cotton to continue to burn otherwise than in the slow and imperfect manner, undergoing a transformation similar in character to destructive distillation.

Centrifugal Pumps.—A paper on centrifugal pumps was read lately before the Institution of Civil Engineers, by Mr. David Thomson, who stated that the first really successful centrifugal pump was that contributed by Appold to the Exhibition of 1851, in which the vanes were bent backward, which mode of construction is still followed in the best pumps. Mr. Thomson says that the depth of the revolving fan or radiating arms should be $\frac{1}{4}$ of the diameter, and that the central opening for the admission of the water should be about $\frac{5}{16}$ of the diameter over the blades. The fan revolves in a case which should be of much larger diameter than the fan itself. The best duty of the pump is given when the speed of the periphery of the fan exceeds the velocity of a body falling through the height of the lift by from 6 to 8 ft. per second. A fan 12 in. in diameter, and proportioned as described, will discharge 1,200 gallons of water per minute, and the delivery, the speed of the periphery of the fan remaining the same, will increase as the square of the diameter. In small pumps the duty is about 55 per cent., and in large about 70 per cent. of the indicator power of the engine from which the motion is derived.

Galvanized Iron.—A method of estimating the quantity of zinc existing in the plating of galvanized iron, has been communicated to the "Philosophical Magazine," by Mr. T. Warren. The principle of this method consists in the use of mercury to dissolve the zinc, when the loss of weight can be easily ascertained. But a thin coating of an amalgam of iron and zinc will remain, which will take up a certain quantity of mercury, and the amount of this amalgam present is measurable by the quantity of mercury it will take up. To determine this quantity of mercury, the iron is weighed, then heated to drive the mercury off, and then weighed again. when the weight of mercury which has mixed with the amalgam will be at once ascertained.

Durability of Cast-Iron Water-Mains.—I took up some 8-in. cast-iron pipe last year, which had been in use since 1828. It was made in Philadelphia, and laid in the mill-yard of the Merrimac Manufacturing Company, in connection with the force-pump, for fire purposes. Until 1849, the head on them did not much exceed 150 ft.; since then it has been about 200 ft., exclusive of the effect of water-hammer.

The interesting point, however, is its state of preservation. Thinking it might be of interest in connection with the proposed discussion, I send a section of the pipe. When taken up it was lined with tubercles, projecting say $\frac{1}{4}$ to $\frac{1}{2}$ of an inch. As the pipes were intended to be relaid, and in fact have been, except 2 or 3 pieces, they were scraped out. The outside remains pretty much as when taken up, except as the rust has jarred off in carting the pipe. Thirty-nine years' use appears to have made but little impression upon it.—*Extract from a Letter from James B. Francis, Civil Engineer, 27th July, 1868, to A. W. Craven, Member of the Am. Soc. of Civil Engineers.*

The Mercurial Battery of Marie Davy.—This galvanic battery, which has lately been extensively and almost exclusively used in France, is not so universally known as it deserves. It is composed of zinc and carbon; but in place of diluted acid the zinc is simply immersed in pure water, while the carbon is immersed in a paste of moistened sulphate of mercury. The chemical action is similar to the Daniell battery, consisting of zinc, copper, and sulphate of copper. The zinc is oxidized at the expense of the water, which is decomposed, its oxygen combining with the zinc, forming oxide of zinc, while the hydrogen in its nascent state reduces the oxide of mercury, combining with the oxygen, forming water, and leaving the mercury in a metallic state. In this condition mercury cannot remain in combination with sulphuric acid. Hence, the latter is also set free and combines with the oxide of zinc, forming sulphate of zinc, exactly as is the case in the Lowe, Daniell, and other batteries, while the metallic mercury collects at the bottom of the vessel. Such a battery may remain in operation for half a year without cleaning or the addition of liquid. The current generated by 40 small elements has the same power as that from 60 of Daniell's larger ones, which lasted less than half the time.—*The Telegrapher.*

The following illustration, says Professor Henry, of the vibratory movement of matter is attested by Professor Horsford, of the United States. The top of the high tower which constitutes the Bunker Hill monument inclines towards the west in the morning and the north at mid-day, and towards the east in the afternoon. These movements are due to the expanding influence of the sun as it warms, in succession, the different sides of the structure. A similar but more marked effect is produced on the dome of the Capitol of Washington, as indicated by the apparent motion of the bob of a long plumb-line fastened to the under side of the roof of the rotunda and extending to the pavement beneath. This bob describes daily an ellipsoidal curve, of which the longer diameter is 4 in. or 5 in. in length. By molecular actions of this kind, Time, the slow but sure destroyer, levels with the ground the loftiest monuments of human pride.

The New York caisson for the East River Bridge was successfully launched on the 8th of May.